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NATURAL REVEGETATION OF RANGE LANDS BASED UPON GROWTH REQUIREMENTS AND LIFE HISTORY OF THE VEGETATION

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INTRODUCTION

Ideal range management would mean the utilization of the forage crop in a way to maintain the lands at their highest state of productiveness and at the same time afford the greatest possible returns to the stock industry. To maintain the maximum productivity, the annual herbage crop must be used in a manner which will not retard the growth or prevent the perpetuation of the most desirable forage species. On the other hand, if the stock industry is to receive the greatest possible returns at all times, the annual forage crop should be used when it is most needed and when the herbage is palatable and nutritious.

It is obvious from this that the requirements of the vegetation and the requirements of the stock are to a great extent antagonistic. Hence, unrestricted grazing, without regard for the vegetation or the locality, eventually results in decreased productivity, and often in denudation.

The decline in carrying capacity of our western grazing lands was brought about in part by injury due to trampling, but perhaps in greater part by premature grazing and overstocking. The growing herbage might be called a laboratory where plant nutrients are prepared, and the repeated removal of the foliage year after year during the fore part of the growing season means the destruction of this laboratory, which in turn means lack of nourishment for the vegetation, resulting in lowered vitality and an inability to produce seed.

The easiest way to overcome the deteriorating effect of premature grazing and overstocking, as well as of trampling, would be, of course, to eliminate grazing entirely. Obviously, however, such a procedure would be impracticable from the standpoint of the stock industry. Since this is so, the best means of solving the problem in a scientific manner is to

approach it as similar problems in farm practice are approached—that is, (1) by a careful study of the vegetation making up the forage crop, (2) by a study of the natural factors upon which depends the success or failure of the forage crop and its perpetuation, and (3) by a study to find a method of grazing which will both fully utilize the forage and at the same time protect it from deterioration.

Such studies were undertaken by the Forest Service in cooperation with the Bureau of Plant Industry during the spring of 1907 in the Wallowa Mountains of northeastern Oregon. While the intensive investigations were confined in the main to this one grazing region, the results have been applied elsewhere with success, notably in the Hayden National Forest in Wyoming. It is possible, of course, that the reproductive capacity of various forage plants may vary in different localities and also that there may be a difference in the behavior of plants on ranges grazed by sheep and those grazed by cattle and horses, any of which may affect the measure of success obtained by deferred grazing, but not the principles involved in the system.

The purely experimental studies were continued throughout the seasons of 1907, 1908, 1909, and 1910 and were followed by a practical application of the principles evolved to range management on lands within the Wallowa National Forest.

The system developed as a result of the studies—a combination of deferred and rotation grazing—is now being applied with minor variations to range lands throughout the National Forests, and promises to be of the greatest value in bringing about the efficient utilization of the forage resources.

This article gives in full the data upon which the new system is based. The area where the intensive studies were carried on is first described. Following this are given the life histories of the important forage species, including growth requirements and the factors influencing the establishment of reproduction. This in turn is followed by a discussion of the relative merits of different systems of grazing. Finally there is presented a rational and economical grazing system based upon the requirements of the forage plants and of the stock industry

TOPOGRAPHY AND SOIL

The Wallowa National Forest, within which the studies were carried on, is a region of high mountains, very irregular and broken. From the Grande Ronde and Wallowa Valleys, which bound the forest at about 3,000 feet elevation, the mountains rise to from 6,000 to 9,500 feet. On the upper reaches of the numerous domes, above the limits of forest growth, snow often remains throughout the summer. In this group of high, snowy peaks, within a radius of about 3 miles, rise nearly all of the streams from which the stock of the region are watered.

The forest exhibits three principal rock formations: Basaltic, granitic, and limestone. These give rise to as many different soil types, which in turn very largely determine the character and density of the vegetation. The best and most luxuriant vegetation is found upon the basaltic soils, which cover the greater part of the region, the comparatively recent lava flows from which they originate having buried the original formationsi n some places to a depth of several hundred feet. They are porous and very friable, admit of about average percolation, and retain water well. The granite and limestone soils, on the other hand, are poorly decomposed and lose moisture rapidly through percolation and evaporation. In consequence the vegetation is usually sparse, only the more drought-resistant plants being able to establish themselves. The limestones, mixed with shales, are the oldest and most restricted of the three formations. The granites, which are of a later period, form the peaks, crests, and soils of the very highest mountains.

CHARACTER AND DISTRIBUTION OF THE VEGETATION

Within the great altitudinal range between the lower valleys and higher mountains of the region wide differences naturally exist in the physical conditions which govern plant growth, and therefore in the character and composition of the growth itself. On the other hand, physical and climatic conditions, and consequently the vegetation, are strikingly similar within certain altitudinal limits, making it possible to divide the region into four climatic zones. Following Merriam's classification[1] these are:

Transition zone (yellow-pine association)	3,000 to 4,500 feet.
Canadian zone (lodgepole-pine association)	4,500 to 6,800 feet.
Hudsonian zone (whitebark-pine association)	6,500 to 8,500 feet.
Arctic-Alpine zone (Alpine-meadow association)	above 8,000 feet.

The altitudinal limits of these zones are not absolutely marked, since altitude does not wholly determine the character and composition of the vegetation. Hence, the limits given above should be considered only approximate for a given locality in this latitude.

THE TRANSITION ZONE.—The Transition zone contains a number of coniferous tree species, the most characteristic being western yellow pine (*Pinus ponderosa*). Toward the upper limits of the zone yellow pine gives way to Douglas fir (*Pseudotsuga taxifolia*) and lowland fir (*Abies grandis*). As a rule, the timber is open, with considerable undergrowth of average palatability and nutritiousness, if grazed relatively early (Pl. XII).

Among the most characteristic and abundant herbaceous species is pine-grass (*Calamagrostis rubescens*). Other species which furnish a large

[1] Merriam, C. Hart. Life zones and crop zones of the United States. U. S. Dept. Agr., Div. Biol. Survey, Bul. 10, 79 p., 1 map. 1898.

part of the herbage on the lower, sparsely timbered lands are big bunch-grass (*Agropyron spicatum*), little bluegrass (*Poa sandbergii*), big blue-grass (*Poa scabrella*), and blue bunch-grass (*Festuca arizonica*). Germination and growth begin in the most exposed situations during the first week in April, and early in May the vegetation shows everywhere throughout the zone. Stock are usually not admitted before May 15.

CANADIAN ZONE.—The Canadian zone is characterized by lodgepole pine (*Pinus murrayana*), the predominant tree of the region. In many places the timber is so dense that there is little or no undergrowth of vegetation. Only the most tolerant shrubs and herbs can exist in the subdued light under the heavy timber, and such lands are of practically no value for grazing. In other places extensive areas of lodgepole pine have been burned over. Sometimes reproduction is established promptly, but where fire has consumed most of the organic matter in the soil, the reestablishment of vegetation of any kind is slow. Among the forerunners in the invasion of permanent species, fireweed (*Chamaenerion angustifolium*), a valuable sheep forage, and pearly everlasting (*Anaphalis margaritacea*), a plant of no forage value, are most common. Both growth and grazing begin in this zone fully 20 days later and end two weeks earlier than in the Transition zone below.

HUDSONIAN ZONE.—The Hudsonian zone, in contrast with the lands immediately below it, is open in character, the timber growing sparingly and in clumps. The predominating vegetation consists of grasses intermixed with various other palatable plants, as shown in Plate XIII, figures 2 and 3.

This zone probably covers a larger area than the two lower zones combined and supports most of the sheep permitted in the Wallowa Forest during the summer growing season. On account of the demands made upon this desirable range and because of the character of the forage, the Hudsonian zone has suffered more serious depletion than any other, and it was here that the most intensive study of revegetation was made.

The trees of the Hudzonian zone, most of which extend to the normal timber line, are Alpine fir (*Abies lasiocarpa*), whitebark pine (*Pinus albicaulis*), Engelmann spruce (*Picea engelmanni*), and mountain hemlock (*Tsuga mertensiana*). Whitebark pine is the most characteristic species, and its altitudinal distribution is so clearly marked that one can be certain wherever it is met that the conditions there are those of the Hudsonian zone. The timber grows in small, dense clumps, precluding an undergrowth of any but the most tolerant species.

Aside from the timber, vegetation is distinctly herbaceous and consists mainly of grasses and nongrasslike plants, commonly termed weeds. While a great many of the species are grazed to a limited extent at one time or another during the season, about 40 furnish 90 per cent of the

range forage. These, arranged in the order of their local forage value, are:

Mountain bunch-grass (*Festuca viridula*).
Little bluegrass (*Poa sandbergii*).
Short-awned brome-grass (*Bromus marginatus*).
Western porcupine, or needle grass (*Stipa occidentalis*).
Smooth wild rye (*Elymus glaucus*).
Tufted hair-grass (*Deschampsia caespitosa*).
Wild celery (*Ligusticum oreganum*).
Onion grass, or mountain bluegrass (*Melica bella*).
Red bunch-grass (*Agropyron flexuosum*).
Mountain wheat-grass (*Agropyron violaceum*).
Yarrow, or wild tansy (*Achillea lanulosa*).
Spiked trisetum (*Trisetum spicatum.*)
Butterweed (*Senecio triangularis*).
Coneflower (*Rudbeckia occidentalis*).
Wild buckwheat (*Polygonum phytolaccaefolium*).
Alpine timothy (*Phleum alpinum*).
Horsemint (*Agastache urticifolia*).
Wood rush (*Juncoides glabratum*).
Nuttall willow (*Salix nutallii*).
Fireweed (*Chamaenerion angustifolium*).
Mountain dandelion (*Agoseris glauca*).
Mountain onion (*Allium validum*).
Little needle grass (*Stipa minor*).
Wild onion (*Allium platyphyllum*).
Wild onion (*Allium collinum*).
Tall swamp-grass (*Carex exsiccata*).
False hellebore (*Veratrum viride*).
Valerian (*Valeriana sitchensis*).
Alpine redtop (*Agrostis rossae*).
Blue beardtongue (*Pentstemon procerus*).
Elk-grass (*Carex geyeri*).
Skunkweed, or Jacob's-ladder (*Polemonium humile*).
Sheep sedge (*Carex illota*).
Reed-grass (*Cinna latifolia*).
Woolly weed, or woolly hieracium (*Hieracium cynoglossoides*).
Onion grass, or mountain bluegrass (*Melica spectabilis*).
Wire sedge (*Carex hoodii*).
Tall meadow grass (*Panicularia nervata*).
Slender hair-grass (*Deschampsia elongata*).
Rush (*Juncus confusus*).
White foxtail (*Sitanion velutinum*).
Parry's-rush (*Juncus parryi*).
Rush (*Juncus mertensianus*).
Rush (*Juncus orthophyllus*).

Throughout the Hudsonian zone mountain bunch-grass (*Festuca viridula*) is by far the most abundant plant and the most desirable to revegetate. The relish with which several of the other species are grazed and their similar altitudinal range and abundance made it very difficult to determine which one ranks next in value, and the arrangement presented was not finally decided upon until after the third year's investigation.

Growth usually begins in the Hudsonian zone about the last week in June, and stock are given access to the lands early in July.

ARCTIC-ALPINE ZONE.—The Arctic-Alpine, or timberless, zone is not only unfavorable to tree growth, but to grazing plants as well. As shown in Plate XIV, figure 1, the zone is confined to the very highest crests and peaks, where the soil is shallow and poorly decomposed, the season of growth short, and nightly frosts common. Owing to the virtual lack of grazing in this region, it was not thought necessary to measure accurately the climatic factors.

The species of the Hudsonian zone are for the most part entirely absent in the Arctic-Alpine. Among the characteristic alpine plants are cat's-foot (*Eriogonum piperi*), whitlow-wort (*Draba aureola*), *Hoorebekia*

lyalli, hulsea (*Hulsea nana*), Alpine phacelia (*Phacelia alpina*), and false strawberry (*Sibbaldia procumbens*). Even these species occur sparingly.

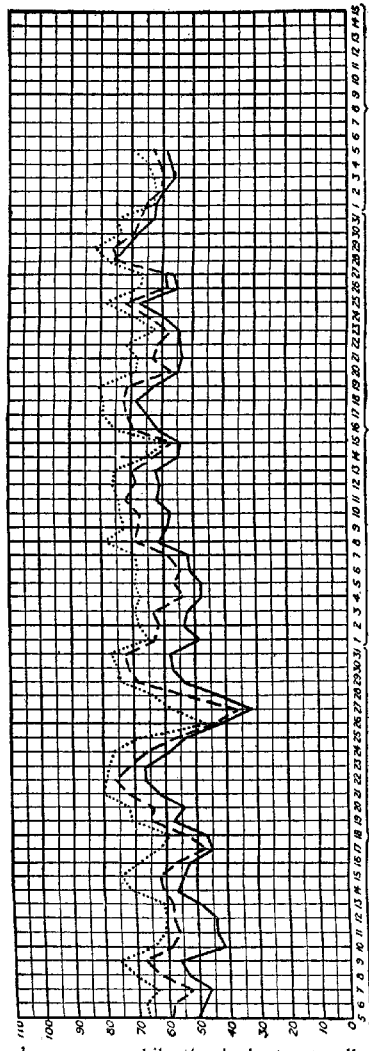

FIG. 1.—Curve showing the variation in the mean temperature in the Transition, Canadian, and Hudsonian grazing zones in 1909.

Growth does not usually begin until well into July and ceases about September 1. Naturally in this zone any species which succeeds in maturing viable seed must be vigorous and able to develop in a short time.

CLIMATE

Records of temperature, precipitation, and air humidity were kept in the Canadian, Transition, and Hudsonian zones during the main grazing season, in order to determine what differences in the season of growth they exhibit.

TEMPERATURE.—Figure 1 shows the mean temperatures of the respective zones derived from the daily maximum and minimum during the main growing season of 1909. While the mean temperatures in the three zones differed widely, there is a close relationship between the daily fluctuations. In all cases the mean is lower, usually by several degrees, in the Hudsonian zone than in the two lower ones, while the highest naturally comes in the Transition zone. The extremes from which the mean temperature was obtained show that

the variation in the maximum temperatures in the three zones is fully as great as in the case of the minimum. During the month of July, for example, the maximum temperature in the Hudsonian zone was 84°; in the Canadian, 90°; and in the Transition, 104° F. The highest temperature in the three zones during the entire growing season was 91°, 97°, and 105° F., respectively.

PRECIPITATION.—The higher temperatures characteristic of the less elevated lands are associated in the region of the study with a minimum precipitation. In the valley surrounding the Wallowa Mountains—that is, in the Transition zone—at an elevation of 3,600 feet, the annual precipitation is about 17 inches, the greater part coming in the spring, autumn, and winter. As a result, the vegetation often suffers for lack of moisture. In the Hudsonian zone, on the other hand, the larger amount of precipitation received is ample, and, with the exception of seedling plants, the vegetation is not affected by drought.

Figure 2 shows that the Transition and Canadian zones received 51.6 and 26 per cent less rainfall, respectively, than the Hudsonian. While

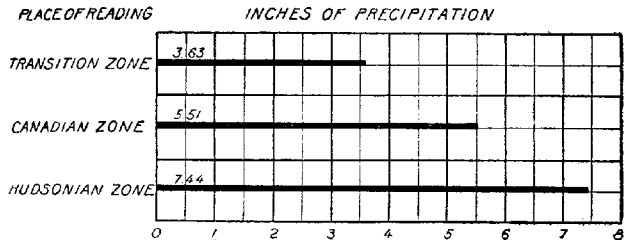

FIG. 2.—Diagram showing the total precipitation in the Transition, Canadian, and Hudsonian grazing zones during July, August, and September, 1909, inclusive.

the actual amount of precipitation during the growing season of 1909 was somewhat above normal, the ratio between the amount which fell in the different zones is similar to that of an average year. The greater amount of precipitation at the higher altitudes, together with the comparatively late date at which growth begins, accounts for the continuous development of the forage.

COMPARATIVE AIR HUMIDITY.—Since the Hudsonian zone has a relatively lower air temperature, a greater amount of precipitation, and a more humid soil than the lower zones, it would be natural to expect that the relative air humidity would be lower and transpiration less severe than in the lower areas. Figure 3, which gives the daily variations in air humidity derived from evaporation readings, shows this to be the case.

It was unexpectedly found that in the Hudsonian zone the evaporation was greater than in the Canadian zone immediately below. While the temperature and even the relative air humidity, as computed from psychrometer readings, were lower in the Hudsonian zone, the dense timber of the Canadian zone so interrupted the air currents as to materi-

ally diminish the evaporation there. In comparing the three zones, however, the evaporation in the Hudsonian and Canadian zones was found to be, respectively, 13 and 35.6 per cent less than that in the Transition zone. Owing to the relative great evaporation in the latter region, light showers, especially those which fall early in the day and are succeeded by a clear sky, are soon evaporated and so are of little value to plant growth. During a period of drought, other things being equal, a plant could not live nearly as long in the lower as in the higher elevations, on account of the excessive transpiration in the former locality.

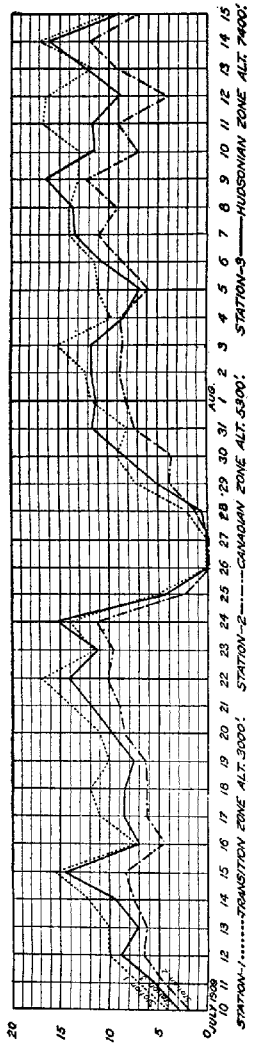

FIG. 3.—Curve showing the comparative daily evaporation in the Transition, Canadian, and Hudsonian zones in 1909.

To sum up the conditions peculiar to the Hudsonian zone as compared with the lower grazing type, the temperature is lower, the precipitation heavier, and the transpiration less. It is therefore easy to see that the relatively slow-growing and warmth-requiring vegetation in the lower lands could not thrive in the cooler and shorter growing season typical of the Hudsonian zone. Hence, only the most plastic and adaptable species of the Transition zone occur in the Hudsonian, and then only on the warmest and most exposed south slopes.

LIFE HISTORY OF THE FORAGE PLANTS

The growth requirements of range plants can best be determined by a study of individual species and the factors with which they have to contend from the time that they begin growth in the spring through the various stages of development to seed maturity, and then on to the permanent establishment and seed-bearing stage of the vegetation produced from seed of the original plants. The essential features of this almost double life cycle are: (1) Inception of growth, (2) flower-stalk

production, (3) development and maturity of seed, (4) viability of the seed crop, and (5) establishment of reproduction.

Owing to the relatively unfavorable conditions for plant growth and the demands made upon them for summer range, the high mountain lands are the ones most in need of revegetation. For this reason the life history of the forage plants and the factors affecting their activities were studied more intensively in the Hudsonian zone than elsewhere.

INCEPTION OF GROWTH

The time at which growth begins in the spring varies widely in the different zones. Thus, in the heart of the Hudsonian zone growth begins ordinarily about five weeks later than in the Canadian zone immediately below and seven weeks later than in the Transition zone. Even in the same zone the beginning of the growth period may vary by as much as 10 days from year to year, depending chiefly upon the climatic conditions during the spring, especially in May and June, but also to a certain extent upon the amount of snow accumulated during the winter. One year the early season may be characterized by warm, sunny days, and as a consequence the snow cover, especially on the more exposed situations, may disappear as early as June 20, though this is rather exceptional. In another year the snowfall in May and June may be as heavy as at any time during the winter. North and east exposures are always later in responding to growth than south and west aspects of the same elevation. Considerable difference exists also in the time when growth begins on different portions of the same slope.

The influence of local conditions on the inception of growth was well shown in the case of a north slope in the Hudsonian zone with an altitude at the crest of 7,850 feet and an incline of from 15° to 18°. With a succession of warm, sunny days the snow began to disappear first from the crest, then from the slope, and finally from the base. As the snow melted, growth began almost immediately. Before it had fairly begun on the slope, however, the crest showed a sparse covering of green, while a similar relation later existed between the slope and the base. In the early part of the season there was a marked difference between the amount of soil moisture at crest, slope, and base, the average percentages being 23.2, 27.6, and 39.9, respectively. As the season advanced, however, moisture conditions gradually became equalized, and in the latter part of the growing season the moisture content of the entire slope was practically uniform. For this reason, though growth began on the crest from three to six days earlier than upon the slope and from seven to nine days in advance of that on the base, toward the end of the growing period the vegetation as a whole presented a strikingly uniform appearance.

The period of growth resumption in each zone lasts ordinarily about 20 days. In the Hudsonian zone this period usually begins about June

25 and terminates about July 15. While climatic conditions have a direct influence upon the time when growth begins, the length of the growth-resumption period in a given locality is determined more by the vigor of the vegetation than by anything else. Where year after year the herbage has been removed prior to the time during which the nutrients necessary for spring growth are stored in the roots, growth begins several days later and vegetative development is strikingly less luxuriant than in the case of plants of the same species which have not been subjected to similar treatment.

FLOWER-STALK PRODUCTION

Under ideal conditions flower stalks begin to appear from 10 days to 2 weeks after growth has started. The stalks make a vigorous height growth, and there is a profusion of inflorescence, which is fertilized at an early date. Actually, however, the period of flower-stalk production is often retarded by cool temperatures and other climatic factors, so that the time the stalks begin to show may vary in different portions of the range as much as several days, similarly to the inception of growth. Obviously the two are closely related, an early and prolific herbage production being followed by an early and luxuriant flower-stalk development, and a late, scanty growth of herbage by a correspondingly late appearance of a few weak stalks.

The vigor of the vegetation and consequently the time and abundance of flower-stalk production are also strongly influenced by the way the lands are grazed. Close cropping, coupled with successive trampling prior to the full development of the plant, delays not only the flower-stalk production, but also the maturing of the seed crop in subsequent years. The period required for an overgrazed plant to regain its vigor depends on the amount of injury received and the situation in which it grows. Three seasons of protection from grazing are usually sufficient for herbaceous vegetation to recover its vigor fully.

To determine the actual difference in the time of flower-stalk production on closely grazed, moderately grazed, and protected areas, as well as the time required for overgrazed plants to recover their lost vigor, observations were made during three successive seasons of mountain bunch-grass areas grazed in different degrees, and on others completely protected from stock. The range selected was at an elevation of 7,300 feet in the heart of the Hudsonian zone. The unprotected or open range was grazed according to the usual practice, the forage crop being removed early in August each year, prior to maturity.

During the first year (1907) no difference was observed in the time of flower-stalk production on the protected and open ranges, since the vegetation on both had previously been weakened through grazing. In 1908 and 1909, however, there was a notable difference in flower-stalk production, as shown in Table I and Plate XV, figure 1.

TABLE I.—*Annual progression in the flower-stalk production on closed areas and open range*

Condition of range.	Period of flower-stalk production.			Estimated percentage of increase in flower stalks.		
	1907	1908	1909	1907	1908	1909
Closed to grazing....	July 10 to Aug. 20.	July 4 to Aug. 10.	July 1 to July 28.	0	20	60
Adjacent range open to grazing.	July 10 to Aug. 20.	July 8 to Aug. 20.	July 8 to Aug. 15.	.....	.....	.....

After the first year of protection mountain bunch-grass produced its flower stalks both earlier and more luxuriantly than on the adjacent range open to grazing. This was also true of other forage species. Though the advance in the time that the flower stalks appeared (4 and 7 days in 1908 and 1909, respectively) was not very great, the stalks were developed more uniformly, the total period required for the function on the protected area being 37 and 28 days in 1908 and 1909, respectively, and on the open area, 43 and 38 days.

To compare flower-stalk production on areas grazed in the usual way and on others protected from grazing until the seed crop can ripen, several small plots of mountain bunch-grass, 1 meter square, were clipped with shears just above the ground for three successive seasons. On half of the quadrats the herbage was clipped once each month, or three times during the growing season, while on the remaining plots cutting was not done until after seed maturity—about September 1. During the fourth and fifth seasons the herbage was undisturbed.

The results showed that in the case of the plots clipped monthly the vegetative growth decreased in abundance each successive season. In the fourth year the undisturbed herbage was exceedingly weak, short, and sparse. No flower stalks were produced until the vegetation had been given one full season of rest, and then only a few late weak stalks were sent up. On the plots clipped after seed maturity, however, the flower stalks were produced fully as early, as uniformly, and as profusely as in the case of the plants which had remained unmolested during the 5-year period. Herbage production was also equal to that on the protected areas.

On the open range, grazed early in the growing season, the flower stalks were produced at irregular periods, a few appearing early in July, the majority coming in August. On yearlong protected areas and on those protected until the seed crop had ripened, the stalks appeared early, practically all being in evidence before August 10.

Early and abundant production of flower stalks is of the utmost importance in seed production. Ordinarily from three to five weeks are

required for the proper development and "filling" of the seed after the flower stalks are produced. Climatic conditions usually become rather severe in the latter part of August, however, and flowers fertilized after the first week in August have not sufficient time to develop and mature their seed. Plants with low vitality are likely to produce flower stalks so late that the seed has no time to mature. A few species which reproduce vegetatively seem to have an inherent tendency toward irregular and late flower-stalk production, and such delay should not be confused with that due to low plant vigor. Of these species, pine-grass and yarrow, or wild tansy, require the longest time to produce flower stalks. On the lowest border of the Transition zone these species actually send up their flower stalks as early as July 10, and on the higher areas continue until inclement weather—about September 15—stops their activities.

PERIOD OF SEED MATURITY

Under the most favorable conditions the time required for the development of seed is about 25 days. The period varies slightly with the length of the growing season and is longest at the lower elevations. It also varies among different species, and the time given for ideal conditions should be considered as approximate.

Naturally the same factors which promote or retard the growth-resumption period and flower-stalk production also determine the time of seed maturity, though the last named fluctuates least, since toward the end of the growing season physical conditions, especially soil moisture and air and soil temperature, tend to become uniform throughout the range.

The length of the seed-maturing period varies widely from year to year as the result of the presence or absence of killing autumn frosts. In 1907 practically no seed of the more valuable perennial herbaceous species were matured in the Hudsonian zone until August 20, while in 1908 the ripening period came at least five days earlier. From this it might appear that the seeds were matured more slowly in 1908 than in 1907. This was not the case, however, the apparent difference being explained by the fact that in 1907 weather conditions after the first week in September were so unfavorable that the seeds which had not matured by that time were destroyed. In 1908, on the other hand, heavy frosts and low temperatures did not appear until September 20, and practically all the seed matured.

In 1908 seeds of mountain bunch-grass and other important species began to ripen on August 15, and by August 25 fully two-thirds of the crop had matured. After September 5 practically no immature seed were to be found, even on the cool north slopes at the higher altitudinal limits of the species. The secondary grazing plants, almost without exception, had matured their entire seed crop by September 10.

In 1909 the seed-maturity period began earlier than in the two preceding seasons. In the case of mountain bunch-grass and a few other species this difference amounted to as much as 10 days in the identical situations observed in previous years. As with the production of flower stalks, the latest period of seed maturity occurred in 1907. The seed of vegetation on the cool and moister north slopes invariably matured later than that on other exposures and on level land at the same altitude, the difference amounting to a week or 10 days. Elevation is, of course, influential in determining the time of seed maturity. Each increase of a thousand feet, other conditions remaining the same, brings about an approximate delay of a week. The chief factor in determining the time of seed maturity, however, as well as the size of the seed crop, is the vigor of the vegetation. Where the herbage had been grazed for several successive seasons when green and the vitality of the vegetation thus lowered, no seed was produced, or else the period of maturity came so late as to be seriously interfered with by frosts and low temperature. In contrast to this, the seed-ripening period on yearlong protected lands and on those not grazed until after seed maturity was much earlier and more uniform, while the amount of seed produced was notably greater.

On the unprotected range there was little difference in the time of seed maturity from year to year. On both the yearlong protected range and that grazed after seed maturity, however, the period came earlier each successive season, in direct ratio with the increase in vigor of the vegetation.

The importance of keeping the vegetation thoroughly vigorous is further exemplified by the clipping experiments. Where the herbage had been removed monthly for three successive seasons, no seed was developed in the fourth year when the plots remained undisturbed. On the other hand, on the plots clipped annually after seed maturity the seed crop was fully as large and matured at the same date as on lands from which stock were excluded.

The experiments show, therefore, that if the forage crop is left undisturbed until the seed has ripened, at which time the plants will have ceased growing, it will produce as large and as early a seed crop the following season as will vegetation on range not grazed at all. Clearly these facts are of the greatest importance in devising a system by which the forage may be grazed without interfering with seed production.

VIABILITY OF THE SEED CROP

The germinative power of the seed of the leading range plants was determined, in order to ascertain what reproduction might be expected under favorable conditions. In Table II, which gives the results of the tests, the high-range and low-range plants are grouped separately.

TABLE II.—*Average fertility of the seed of range plants from 1907 to 1909, inclusive*[a]

Name of plant.		Seed fertility (germination).
Common.	Scientific.	
	PLANTS OF THE HIGH RANGE	*Per cent.*
Mountain bunch-grass	Festuca viridula	12.2
Little bluegrass	Poa sandbergii	7.0
Short-awned brome-grass	Bromus marginatus	47.6
Tufted hair-grass	Deschampsia caespitosa	26.4
Onion grass, or mountain bluegrass	Melica bella	4.0
Reed-grass	Cinna latifolia	86.8
Alpine redtop	Agrostis rossae	36.0
Smooth wild rye	Elymus glaucus	21.2
Alpine timothy	Phleum alpinum	69.5
Western porcupine, or needle grass	Stipa occidentalis	27.0
White foxtail	Sutanion velutinum	69.5
Little needle grass	Stipa minor	29.8
Elk-grass	Carex geyeri	21.3
Tall swamp-grass	Carex exsiccata	15.2
Sheep sedge	Carex illota	27.5
Wire sedge	Carex hoodi	.....
Wood rush	Juncoides glabratum	7.5
Mountain onion	Allium validum	37.0
False hellebore	Veratum viride	24.0
Skunkweed, or Jacob's-ladder	Polemonium humile	42.0
Wild celery	Ligusticum oreganum	6.5
Blue beardtongue	Pentstemon procerus	18.5
Wild buckwheat	Polygonum phytolaccaefolium	9.5
Horsemint	Agastache urticifolia	22.2
Mountain dandelion	Agoseris glauca	36.0
Woolly weed	Hieracium cynoglossoides	10.9
Yarrow, or wild tansy	Achillea lanulosa	27.8
Coneflower	Rudbeckia occidentalis	21.8
Average germination		28.3
	PLANTS OF THE LOW RANGE	
Big bunch-grass	Agropyron spicatum	24.3
Pine-grass	Calamagrostis rubescens	69.6
Marsh pine-grass, or bluejoint	Calamagrostis canadensis	71.5
Mountain June-grass	Koeleria cristata	15.0
Slender hair-grass	Deschampsia elongata	41.6
Soft cheat	Bromus hordeaceus	48.2
Tall meadow-grass	Panicularia nervata	85.0
Geranium	Geranium viscosissimum	29.5
Fireweed	Chamaenerion angustifolium	21.5
Average germination		45.1

[a] In the case of a few species listed seed tests were made during two seasons only.

It will be observed that the viability of the seed of most plants is low. In the case of the important mountain bunch-grass, for example, barely more than one-tenth of the seed germinates. In a few cases mountain

bunch-grass seed showed a fair viability, the maximum germination obtained being 25.2 per cent, but the average of a great number of tests made under various degrees of temperature gave the figure in the table. In general, seed of the less desirable species, such as white foxtail and reed-grass, show a higher percentage of germination than that of mountain bunch-grass, short-awned brome-grass, and others. The germinative power of the seed was generally lowest in 1907, owing to the low vitality of the vegetation due to previous early grazing. In subsequent seasons on areas protected entirely from stock or until the seed had matured there was a pronounced increase in the germinative power of the seed.

It will be seen from Table II that, in general, seed fertility decreases with elevation, the average germination of the plants on the higher ranges being only 28 per cent, as against 45.1 per cent for those on the lower elevations. Even with the best conditions of growth and plant vigor, the vegetation of the region must struggle to mature its seed during a short and none too favorable growing season. The effect of exposure and of low vigor of the vegetation (as indicated by the date of maturity) on the germinative power of the seed is shown in Table III.

TABLE III.—*Effect of exposure and date of maturity upon germination of mountain bunch-grass*

Series No.	Source of seed.	Altitude.	Date of maturity.	Germination.
		Feet.		*Per cent.*
1	South exposure	7,400	Aug. 20	14.0
2	West exposure	7,400	Aug. 22	9.5
3	North exposure	7,300	Sept. 1	11.5
4	East exposure	7,350	...do....	11.0
5	South exposure	7,400	Aug. 31	7.0
6	West exposure	7,400	...do....	4.5
7	North exposure	7,300	Sept. 12	1.5
8	East exposure	7,350	Sept. 14	0

The data in this table bring out two important facts: (1) There is no difference in the vitality of the seed of mountain bunch-grass ripening before September 1, provided the variation in the maturing period does not exceed about 10 days. (2) There is a pronounced difference in the viability of seed which reaches maturity by September 1, as compared with seeds ripened September 10 or later, the latter showing practically no germinative power.

The same relationship between the germinative power of early and late-maturing seed was observed in the course of field sowing in the natural habitats, though in all such cases the germinative power of both classes of seed was higher.

The essential conclusions regarding seed germination are:

1. Even under the most favorable conditions the viability of the seed of practically all the forage species is low, especially on the high mountain lands.

2. Late resumption of growth in the spring and low plant vigor, both of which can be traced directly to premature grazing, result in a decrease in the amount of seed produced and in the germinative power of the seed itself.

3. If viable seed is to be produced, the vegetation must not be habitually deprived of its leafy foliage during the critical growing and food-storing period.

SCATTERING AND PLANTING OF THE SEED

But little time elapses between seed maturity and dissemination. This fact is highly advantageous, in that grazing may begin almost immediately after the seed matures without danger of having the crop consumed.

The distance the seed is carried from the parent plant depends chiefly upon the species and the wind. Grasses and grass-like plants, such as sedges and rushes, drop their seed near the parent plant. Those of plants like fireweed (*Epilobium* spp.) and *Crepis* spp., which are provided with bristly capillary hairs and pappus, and those of false hellebore, which are winged, are carried relatively great distances by the wind. Fireweed and dandelion do not grow in as dense stands as the grasses, but, as a rule, are more widely distributed over the range. About 90 per cent of the forage species depend primarily upon wind and water for the distribution of their seed. The remaining 10 per cent, of which huckleberry is an example, depend very largely upon animals for dispersal.

To insure reproduction of the forage plants, the seed must in some way get itself planted. Though nearly all seed will germinate on the surface of the ground where there is abundant moisture, the resulting seedling plants in a locality where the soil dries out early in the season are unable to extend their limited root systems deeply enough to reach the moist lower strata and consequently die from drought.

The size and character of the seed play an important part in the natural reproduction of range plants. The seed of some of the most important species, such as mountain bunch-grass, short-awned brome-grass, and wild celery, are large and light, and even though dropped promptly upon maturity in the autumn, months before germination takes place, are usually found uncovered on the ground in the spring. On the other hand, the seeds of wild onion and some of the sedges and rushes are smaller and heavier and have less difficulty in working into the soil. Among the valuable grasses observed, only one had become planted through natural means. This one exception was western porcupine grass, which is becoming securely established on the range not only in localities where it is abundant, but often on the tightly packed soils of denuded trails,

on hillside terraces formed by the trailing of sheep, and, in fact, everywhere that its seed is developed. In favorable situations 1 square meter of surface showed as many as 700 seedlings of porcupine grass in the spring of the year. This unusual aggressiveness is not due, as might be expected, to exceptionally strong seed habits, but chiefly to the morphology of the scale, or lemma, which closely envelops the seed. The scale is very rigid, with an awn about 1½ inches long protruding from the apex. At maturity this awn is tightly twisted, as shown in Plate XV, figure 2, but when moistened it untwists vigorously, causing the bent, needle-like point at the lower end of the scale to bore into the ground, the stiff, backward-turning hairs holding it in the earth when once started. The repeated twisting and untwisting of the awn with variation in the moisture finally results in the complete burial of the seed prior to the germination period.

Thus, if the seed of the valuable forage species is not planted by artificial stirring of the soil, undesirable species, such as white foxtail, may become established at the expense of the valuable range plants.

GROWTH AND ESTABLISHMENT OF REPRODUCTION OF FORAGE PLANTS

The production of a seed crop of high viability does not necessarily mean any material increase in the forage stand. The seedling plants are often seriously injured or destroyed in the fore part of the grazing season by low temperature and lack of soil moisture. Certain plants are not subject to as serious injury as others, and so the ultimate stand may consist of a single species. The growth and vitality of reproduction will be discussed under three heads: (1) "Development and loss of forage seedlings during first year;" (2) "Loss of forage seedlings during dormant period following first year;" and (3) "Growth and loss of forage seedlings during second and subsequent seasons."

DEVELOPMENT AND LOSS OF FORAGE SEEDLINGS DURING FIRST YEAR

During the first season of growth in the Hudsonian zone, approximately 10 weeks long, the seedlings do not grow tall enough to produce forage, though the young plants are sometimes cropped to a limited extent in the autumn. The height attained by mountain bunch-grass, as well as the root development, is shown in Plate XV, figure 3. It will be seen that the depth of the root slightly exceeds the height of that portion of the plant above ground. This plant represents about the average development of a forage seedling on well-drained and drier situations during the initial year of growth. On the lower elevations, owing to the longer growing season, the seedling plants usually attain much greater development than the one shown.

Observations extending over five successive seasons show that in normal years the low temperatures characteristic of the Hudsonian zone are responsible for considerable loss of seedlings during the first year of

growth. The extent of this influence is shown in figure 4. It will be observed that freezing temperatures occurred on three nights in July, 1909—namely, July 12, 17, and 27—the temperatures recorded being 30°, 23°, and 29° F., respectively. In August freezing temperatures occurred on the 1st, 4th, 20th, and 26th, the lowest being on the night of the 4th, when the temperature registered 28° F. Only on the nights of freezing temperature in July, however, was serious harm done, and then only to the young seedling plants. The greatest injury occurred on the more moist, but not marshy, situations, where the surface soil heaved as a result of alternate freezing and thawing. This action of the soil exposed portions of the roots of the seedlings, leaving them at the mercy of the sun and wind. In a few exceptional cases 50 per cent of the seedling stand was thus destroyed. The freezing temperatures during August were not destructive, since then the root systems were better developed and there was less heaving of the soil, on account of the lower moisture content of the surface layer.

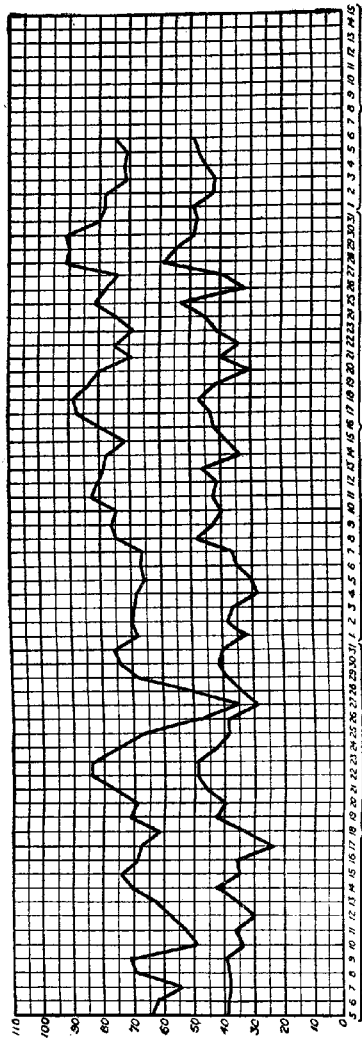

FIG. 4.—Curve showing the maximum and minimum temperature records in the Hudsonian zone (whitebark-pine association).

Because of the high elevation of the Hudsonian zone, the maximum temperature rarely exceeds 90° F. and, as a rule, does not seriously hamper the activities of the vegetation, though, in so far as it influences

the relative air humidity and increases transpiration and evaporation from the soil, it also decreases the available soil moisture.

With the limited amount of precipitation during the growing period in the region, the soil moisture gradually decreases as the season advances. Low temperatures and lack of moisture in the upper soil often work together to destroy seedlings, in that the seedling roots are first pushed up by the heaving of the soil during freezing to a point where there is not enough moisture available for growth.

The seedlings of no particular species seemed to suffer more seriously than any other in the same situation. Individuals which sprang from seed that had not found its way into the soil and which therefore had comparatively shallow root systems were, of course, the most seriously affected.

Plants of the same species growing in the same situation often exhibited contrasts in their ability to withstand drought, and when plants growing in different kinds of soil were observed, the contrast was great. This is shown in Table IV.

TABLE IV.—*Water content of soil at time of death of forage seedlings*

Name of plant, soil type, and situation.	Number of successive days of wilting.	Date of death.	Percentage of nonavailable water.	Average percentage of nonavailable water for each species.
Mountain bunch-grass:				
Basaltic clay loam—				
Quadrat station 4	8	July 22	6.8	.....
Seeded area	6	20	6.3	.....
Do	9	24	6.8	.....
Quadrat station 4, seedlings in flats	6	19	6.2	.....
Do	5	20	6.1	.....
Do	5	21	6.2	.....
Seeded area	10	23	7.2	6.51
Gravelly clay loam—				
Seeded area, seedlings in flats	4	19	5.4	.....
Do	5	19	5.7	.....
Do	3	20	5.4	.....
Do	6	.....	.....	.....
West slope	4	18	5.4	.....
Do	(?)	18	5.3	.....
South slope	5	19	5.4	.....
Do	4	18	5.6	.....
East slope	5	19	5.6	5.5
Western porcupine grass:				
Gravelly clay loam—				
West slope	6	21	5.2	.....
South slope	7	21	5.4	.....
East slope	6	21	5.2	5.26
Short-awned brome-grass:				
Gravelly clay loam—				
West slope	4	19	5.8	.....
South slope	3	19	5.6	.....
East slope	4	18	5.9	5.75

The figures in Table IV show two important facts: (1) In the finer soils a higher percentage of water is required to maintain the life of a seedling than in soils of coarser texture; and (2) mountain bunch-grass requires but little more available water than western porcupine grass, one of the deepest rooted species, to become established in a given soil. Mountain bunch-grass, moreover, will thrive on a soil containing less water than would be required for short-awned brome-grass. To judge from the nature of the situations invaded by mountain bunch-grass, the plant may safely be classed among the drought-resistant native species.

Numerous observations in 1909, supplemented by many counts on small unit areas in different range types and on different soils, showed that nearly the entire loss of seedlings occurred before August 1. After that date loss was prevented by cooler temperatures and by an increase in soil moisture resulting from precipitation. However, the loss before August 1 had been rather severe, varying from 20 to 70 per cent, according to the situation, with a general average of about 50 per cent.

In 1910 the seedling loss in the fore part of the season was approximately the same as in 1909, but the loss in the latter part was much greater, and only 25 per cent of the original stand remained vigorous and active in the autumn. This extensive loss was due to continued dry weather and high temperatures.

LOSS OF FORAGE SEEDLINGS DURING DORMANT PERIOD FOLLOWING FIRST YEAR

Table V shows that, in general, the loss of forage seedlings due to physical conditions from October 1, 1909, to July 1, 1910, approximately, was practically negligible. It will be seen that the heaviest seedling loss occurred on steep slopes, particularly on those where the soil was coarse and gravelly and the vegetation sparse. Quadrats 14 and 16 show this strikingly. The soil in quadrat 14, whose slope is 28.5° to the west, is very coarse and gravelly, and only one-tenth of the ground was covered with vegetation. In quadrat 16, with a slope of 3° to the south, the soil is mainly of clay loam, with a small amount of gravel, and three-tenths of the ground was covered with the same kind of vegetation as quadrat 14. The loss of seedlings on the two quadrats was 28.4 and 1.4 per cent, respectively. These losses were not due to severe temperatures, but primarily to heaving of the soil and erosion before growth began. Additional contrasts can be seen in quadrats 3 and 5, and 31 and 55.

TABLE V.—*Loss of forage seedlings during the dormant and winter period*

Number of each seedling species.	Quadrat No.	Slope and exposure.	Total number of vigorous seedlings remaining— Autumn of 1909.	Total number of vigorous seedlings remaining— Spring of 1910.	Loss.
					Per cent.
80 Mountain bunch-grass	3	25° west	81	71	12.3
1 Western porcupine grass				.....	.....
244 Mountain bunch-grass	5	18° west	248	238	.....
4 Elk-grass				3	2.8
58 Mountain bunch-grass	13	16° west	59	55	7.0
1 Sickle sedge				0	.....
116 Mountain bunch-grass	14	28.5° west	116	83	28.4
61 Western porcupine grass	16	3° south	68	60	1.4
7 Yarrow				7	.....
116 Western porcupine grass	31	11° southeast	138	92	26.3
17 Mountain bunch-grass				6	.....
30 Smooth wild rye	35	12° south	37	29	8.1
7 Western porcupine grass				5	.....
27 Smooth wild rye	38	4° southeast	29	24	17.2
2 Little bluegrass				0	.....
138 Little bluegrass	42	11.5° south	155	134	3.1
9 Smooth wild rye				8	.....
6 Yarrow				6	.....
2 Mountain bunch-grass				2	.....
128 Smooth wild rye	44	4° south	148	126	2.7
11 Yarrow				10	.....
9 Crepis (sp.?)				8	.....
91 Western porcupine grass	55	10° east	91	81	10.9

On steep hillsides where the original vegetation and network of roots had been seriously injured in the autumn by trampling, erosion carried the seedlings away or exposed portions of the more superficial (lateral) roots. Of the seedling loss during the resting period, 80 per cent was brought about in this way, though even this was nominal, averaging in the location studied only 7.3 per cent of the total stand.

Low temperatures were apparently responsible for the loss not directly due to gullying, but such loss was evident only in exposed situations. Practically all of the mountain lands are covered with a heavy blanket of snow before severe temperatures begin, which prevents excessive loss of water through the plant tissues aboveground and eliminates loss due to alternate freezing and thawing. No particular species appear to be especially immune to loss during the winter months. The roots of little bluegrass and sickle sedge seem to be exposed somewhat oftener than those of mountain bunch-grass, porcupine grass, short-awned brome-grass, and other species in the same situations. Mountain bunch-grass seedlings developed a rather unusually elaborate root system during the first year, which assisted in protecting them against adverse conditions.

GROWTH AND LOSS OF FORAGE SEEDLINGS DURING SECOND AND SUBSEQUENT SEASONS

During the second year nearly all species make vigorous growth, both above and below ground. Plate XVI shows the deep and spreading character of the roots of 2-year-old mountain bunch-grass (natural size) at the end of the second season. It will be seen that the roots are much longer than the leaf blades. The vertical roots reach well beyond the dry substratum during the most critical period of drought. The leaf blades, which number about 70 or 80 on the more vigorous individuals, are all basal, with an average length of about 4 inches, about half that of the deepest roots. This splendid root and herbage development provides the plant with abundant food-storage tissue, so that in the following season vigorous growth begins promptly.

During the third year the development of the plant is quite as marked as during the two preceding seasons (cf. Pls. XVI and XVII). Both roots and herbage grow rapidly from the first, though the growth of the former still greatly exceeds that of the leaf blades. Such development is essential, for the roots absorb moisture slowly, and where transpiration is great, nothing short of a well-developed root system can supply the plant with the moisture it requires. Owing to the depth and spread of the roots, the question of available soil moisture is not a serious one, since an ample supply exists 3 inches below the surface layer. At the start of the growing period there is a superabundant supply of moisture, and plants whose roots are well beneath the surface soil continue to extend them more deeply until the innumerable root hairs have worked themselves through the capillary spaces among the soil particles, thus insuring the plant against drought.

By the end of the third year mountain bunch-grass and other species complete their life cycles, and cease to be seedlings. Flower stalks and seed are then produced, as shown in Plate XVIII. At this time the plants are often as tall as older individuals. The specimen shown in Plate XVIII exhibits the maximum development attained, the average growth being shown in Plate XVII. The flower stalks (there are seldom more than three) of the 3-year-old plants as a rule are put forth a few days later than those of the parent or older plants. Consequently the seeds are not matured as early as are those of the longer established individuals, though the variation rarely exceeds five days. So extensive is the development of the plants by the second year of growth that the loss during that and subsequent seasons owing to climatic factors is negligible.

The facts derived from the study of the life history of the vegetation, which are important as a basis for a rational and practical grazing system, may be summarized as follows:

1. The flower stalks of the important grazing plants begin to appear about July 5 and are for the most part produced between that date and August 10. The more vigorous plants send up their flower stalks first. Plants weakened by annual close and early grazing do not produce flower stalks until late in the season, and then send up only a few.

2. The seeds begin to mature by August 15, and by September 1 the major part of the seed crop is ripened and disseminated. Plants weakened by close and early grazing do not mature seed unless the growing season is unusually long and exceptionally favorable.

3. The viability of the seed of most species is low. The germinative power varies with different species, but especially with the vigor of the plants. Those which make a weak vegetative growth produce seed of very low viability.

4. The seeds of the most valuable species lack means for working themselves into the ground, and, if reproduction is to be secured, they must be artificially covered.

5. In the Hudsonian zone the germination period begins about June 25, and growth begins generally by July 15.

6. During the first year of growth, a period of about 10 weeks, the forage seedlings make a vigorous development. Owing to the friability of the surface soil, however, and the superficial position of the roots at that time, there is rather a heavy loss of seedlings from freezing and drought during the spring period.

7. During the dormant periods there is virtually no loss of seedlings. The only factor causing loss is erosion.

8. In the second and subsequent seasons physical conditions are favorable to rapid development and growth of the young plants. By the end of the third season viable seed is produced.

DIFFERENT GRAZING SYSTEMS IN THEIR RELATION TO GROWTH REQUIREMENTS AND REVEGETATION

From the facts brought out by the life-history studies it is plain that a rational method of grazing should (1) avoid weakening the vegetation through continuous grazing prior to seed maturity; (2) utilize, so far as practicable, the trampling of the animals in planting the seed; and (3) provide for protecting the reproduction against heavy grazing until it is firmly established.

At the present time grazing on the National Forests is carried out under one of three more or less distinct systems: (1) Yearlong or season-long grazing year after year; (2) yearlong or season-long grazing combined with an occasional total restriction of stock during the entire year for the purpose of giving the forage plants a chance to reproduce; and (3) deferred grazing, which aims at a rotation in the time of using each portion of the range, each year allowing an area to reach seed maturity

before it is cropped, but grazing it after that period, in order to avoid loss of forage through nonuse and to assist reproduction by trampling in the seed.

In the following pages the comparative merits of the three grazing systems, from the standpoint of the requirements of the range plants for growth and reproduction, are discussed.

YEARLONG GRAZING

The term "grazing system" implies a definite plan of utilizing the forage crop in accordance with certain basic principles. Yearlong or season-long grazing, however, is characterized mainly by a lack of system, since it fails to provide for the removal of the herbage at any particular time in any locality. Its ultimate results to stock and the range are not considered.

It was this unrestricted grazing on National Forest lands prior to their inclusion that so seriously reduced the carrying capacity of the choice ranges. After the creation of the National Forests overstocking was eliminated as rapidly as the stockmen could meet the necessary reductions, and regular grazing seasons were established. Even under seasonal regulations, however, the prevailing practice of yearlong grazing has not been conducive to the most rapid improvement of the range. In northeastern Oregon sheep are permitted to enter the mountain grazing areas early in July, when mountain bunch-grass and most of the other palatable species begin to put forth their flower stalks. Up to August 1 the flower stalks are virtually as palatable as the leaf blades, and where the range is stocked to its full capacity, as it is in practically all cases, most of the stalks are removed prior to the formation of seed. Moreover, there is a tendency to graze the same lands prematurely each year, a practice which impairs herbage development. This not only prevents seed production, but also results in gradually decreasing the carrying capacity of the range through starvation of the forage plants. Prior to the time of seed maturity practically all of the range has been grazed over at least once, and, as a rule, only the vegetation on the inaccessible lands is allowed to mature seed.

After about August 1 the flower stalks are not eaten as a general rule, except in the case of certain moisture-loving species, such as butterweed (*Senecio triangularis*), but the vegetative portion, especially of the grasses, is so closely consumed as to prevent the manufacture of the food so essential to the development of the plants and the production of seed. Since the main seed-developing period in the Hudsonian zone comes in August, lack of an abundant food supply during the growth period is reflected in the low viability of the meager seed crop produced.

To determine which species are becoming established under the system of yearlong grazing, several typical areas, overgrazed in various degrees,

were studied in 1907 before the stock was turned on to them. Full notes were taken on about 300 plots, 1 meter square. The lands selected were of the open, parklike type, with a scattered growth of whitebark pine and occasional clumps of alpine fir. Mountain bunch-grass was the predominating herbage species. Certain portions of these ranges were seriously depleted, and the usual succession of early, aggressive annual weeds had replaced the original perennial type. At this altitude the annual plants are of little value for forage, though grazed to a limited extent in the spring when succulent and tender. On this account the annual plants are not included in Table VI, which gives the results of the two seasons' observations

TABLE VI.—*Seedling reproduction of perennial forage plants on mountain range areas in 1907 and 1908 under yearlong grazing*

1907

Date of observations.	Locality.	Slope and aspect.	Character of soil.	Percentage of moisture in soil.		Most characteristic species.	Percentage of ground covered by vegetation.	Number of unit areas counted.	Total number of seedlings.	Average number of seedlings per square meter.
				Minimum.	Average.					
August 5 and 6	Stanley Range (elevation, 7,400 to 7,600 ft.).	2° west	Gravelly clay loam	11.4	20.1	Little needle grass, Alpine redtop, and sickle sedge.	10	45	428	9.51
August 6 and 7	do	5° west	Light sandy loam	10.6	20.1	Mountain bunch-grass, onion grass, or mountain bluegrass, and short-awned brome-grass.	50	36	183	5.08
August 9 and 10	do	10° to 20° east	Clay loam	6.2	14.6	Elk-grass, sickle sedge, and short-awned brome-grass.	50	35	157	4.48
August 11	do	12° to 20° south	do	7.1	13.6	Elk-grass and short-awned brome-grass	40	10	16	1.60
August 13	do	5° north	Sandy clay loam	6.4	22.3	Mountain bunch-grass, Festuca ovina, and onion grass.	40	32	190	5.93
August 20	Sturgill Range (elevation, 7,700 to 7,800 ft.).	1° to 2° southwest	Deep sandy loam	23.4	30.2	Sickle sedge	(a)	25	674	26.96
August 20	do	5° south	Shallow, gravelly loam.	13.6	8.3	Mountain bunch-grass, little bluegrass, little needle grass, and Carex spp.	20	26	70	2.67
August 21	do	Level	Clay loam	7.1	8.2	Mountain bunch-grass, and big bunch-grass	20	10	1	.10
August 21	do	5° to 10° south	Gravelly clay loam.	10.3	6.5	Elk-grass and mountain bunch-grass	30	12	23	1.91
August 22	do	3° to 5° southwest	do	9.6	8.9	Mountain bunch-grass, onion grass, and elk-grass.	30	22	55	2.50
August 23	do	10° to 15° south	do	8.6	7.2	Elk-grass, and big bunch-grass	20	26	18	.69
August 23	do	5° to 10° east	Sandy, gravelly	10.1		Mountain wheat-grass (*Agropyron violaceum*) and elk-grass.	20	18	10	.55

1908

July 20	Stanley Range (elevation, 7,400 to 7,600 ft.).	10° to 20° east	Clayey loam	10.8	17.3	Elk-grass, sickle sedge, and short-awned brome-grass.	60	16	69	4.3
July 20 and 21	do	1° west	Gravelly clay loam.	12.0	29.6	Alpine redtop, sickle sedge, and little needle grass.	12	22	286	13.0
July 22 and 23	do	5° west	Clay loam	5.9	24.0	Mountain bunch-grass, onion grass, and spiked trisetum.	20	26	130	5.0
July 25 and 27	do	15° to 20° east	do	8.6	19.3	Elk-grass, sickle sedge, and short-awned brome-grass.	50	14	74	5.3
July 27	do	5° southwest	do	9.2	26.4	Mountain bunch-grass, short-awned brome-grass, spiked trisetum, and onion grass.	15	24	170	7.2
July 28	Sturgill Range (elevation, 7,600 to 7,800 ft.).	1° to 2° southwest	Deep clay loam	21.2	34.7	Sickle sedge, yarrow, little needle grass, and western porcupine grass.	(b)	17	401	23.6
July 29 and 30	do	3.6° southwest	Clay loam	9.0	22.0	Mountain bunch-grass, big bunch-grass, and little bluegrass.	40	12	50	4.2
July 31	do	5° south	Gravelly clay loam.	5.4	16.1	Little needle grass and big bunch-grass	20	14	49	3.5
August 3	do	Level	do	8.5	17.8	Little bluegrass and little needle grass	10	9	36	4.0
August 4 and 5	do	4° to 7° south	Clayey loam	9.3	11.8	Mountain bunch-grass, elk-grass, smooth wild rye, and horsemint.	25	11	36	3.3
August 8 and 9	do	5° east	Gravelly clay loam.	11.0	18.0	Mountain bunch-grass, onion grass, and little bluegrass.	40	12	76	6.4
August 10	do	Level	do	8.2	14.8	Big bunch-grass, western porcupine grass, and sickle sedge.	35	14	57.4	4.1
August 13	do	7° south	Black loam	16.4	28.2	Elk-grass, sickle sedge, slender hair-grass, and tufted hair-grass.	60	10	113	11.3

a Denuded.

b Almost denuded.

The data given in Table VI, supplemented by observations made in 1908 and 1909, show conclusively that on the typical lands studied the important perennial forage species are not being reestablished. For example, such important species as mountain bunch-grass, little blue-grass, and big bunch-grass gave a maximum count of 6.4 seedlings per square meter, as opposed to one of 26.96 for sickle sedge, a species of little value. Even on the lands which still support a fair stand of the original valuable forage virtually no reproduction is taking place. Mountain bunch-grass, which produces flower stalks at a relatively early date, and whose chances are therefore good for maturing a viable seed crop, shows no reproduction from seed where the ranges are grazed each year before the first week in August.

Practically all the seedlings on these ranges are of inferior species. Sickle sedge, an unpalatable but aggressive perennial, forms not less than nine-tenths of the total perennial seedling stand. This sedge matures a strong seed crop at a relatively early date and, in addition, perpetuates itself abundantly by offshoots from the rootstocks, which later develop seed. Besides sickle sedge, there was an occasional seedling of western porcupine grass, little needle grass, short-awned brome-grass, and slender hair-grass. The first three species are fairly good range plants, but the last named is grazed only to a limited extent early in the season. Probably because of this fact slender-hair-grass seedlings were more in evidence than any of the others.

The maximum seedling density occurred on old bed grounds, where the vegetative cover was exceedingly scarce. The average number of seedlings obtained per square meter for all counts made upon such lands was 26.96 and 23.6 in 1907 and 1908, respectively. This exceeds by about 50 per cent the seedling stand for any other type of range examined. There are three chief reasons why the seedling stand is dense on bed grounds: (1) The unpalatability of the parent species, coupled with early maturity of the seed; (2) thoroughness with which the seed is planted; and (3) relatively high water content of the soil.

The seed of sickle sedge usually matures and drops before August 1, and in consequence the plant is neither weakened nor the seed production interfered with by foraging animals. Though on most bed grounds the soil is hard-packed, on the particular ones examined it was loose and porous, and the trampling assisted in conserving its moisture by pulverizing the surface. During the main growing season in 1907 and 1908 the soil moisture content of the bed ground averaged 30.2 per cent, exceeding by 7.9 per cent that of any other locality studied, except the swales.

To sum up, it may be said that season-long grazing continued year after year seriously interferes with the growth of the vegetation, decreasing both the quantity and palatability of the forage crop. By the

failure of the forage plants to produce seed, reproduction is prevented, resulting in a gradual decline in the carrying capacity of the lands. Even under conservative use the carrying capacity of the range does not improve rapidly through reproduction of the more desirable species.

YEARLONG PROTECTION

To determine the practicability of reseeding the range through yearlong protection from grazing, five typical overgrazed areas, situated at various elevations from 3,000 to 7,500 feet, were selected for study. Each area was fenced in 1907, and observations were made during four successive seasons. The results from the areas in each zone are presented separately.

HUDSONIAN ZONE.—The areas closed to stock in the Hudsonian zone had been subjected to close yearlong grazing for several seasons (Pl. XXI, figs. 2 and 3), and because of the resultant low vitality of the vegetation practically no seed was produced during the first two seasons. In the third and subsequent seasons, however, a satisfactory seed crop of average viability was produced. The vegetative changes which took place in representative quadrats are shown in text figures 5 and 6.

It will be seen that at the time of their establishment the quadrats contained no perennial forage seedlings. The first year passed without any making their appearance. In 1909, however, 7 seedlings appeared after the germination period, but, as shown in figure 6, only 5 survived the subsequent dry season. On the denuded quadrat (fig. 6, quadrat 2) 2 mountain-bunch-grass seedlings came in during 1908, both of which succumbed later. In 1909, 10 seedlings were found in the spring, only 6 of which survived the season. Seed was produced in abundance each year, but for the most part remained on the surface of the soil. At the beginning of the study the quadrats were stocked with an inconspicuous and useless plant called knotweed (*Polygonum ramosissimum*), which is common on overgrazed ranges throughout the mountain-bunch-grass association. On the permanent quadrats this species no more than held its own, but on the denuded plots it increased prodigiously.

The contrast in the aggressiveness of reproduction of the annual and perennial species on protected areas, as shown in the case of mountain bunch-grass and knotweed, holds generally. The only perennial species which reproduced well under yearlong protection was western porcupine grass, the seed of which, as already pointed out, is planted by means of an awn attached to the floral glume.

The fact that practically no reproduction from seed was secured as a result of yearlong protection does not necessarily mean that such protection will not bring about an increase in the carrying capacity of the range. As a matter of fact the carrying capacity was increased through the production by the original perennial plants of more and longer leaf

blades and by an increase in the size of existing tufts or hummocks of tussock-forming plants. The leaf-blade increment is shown in Plate XXI, figures 2 and 3, where contiguous areas protected and grazed annually

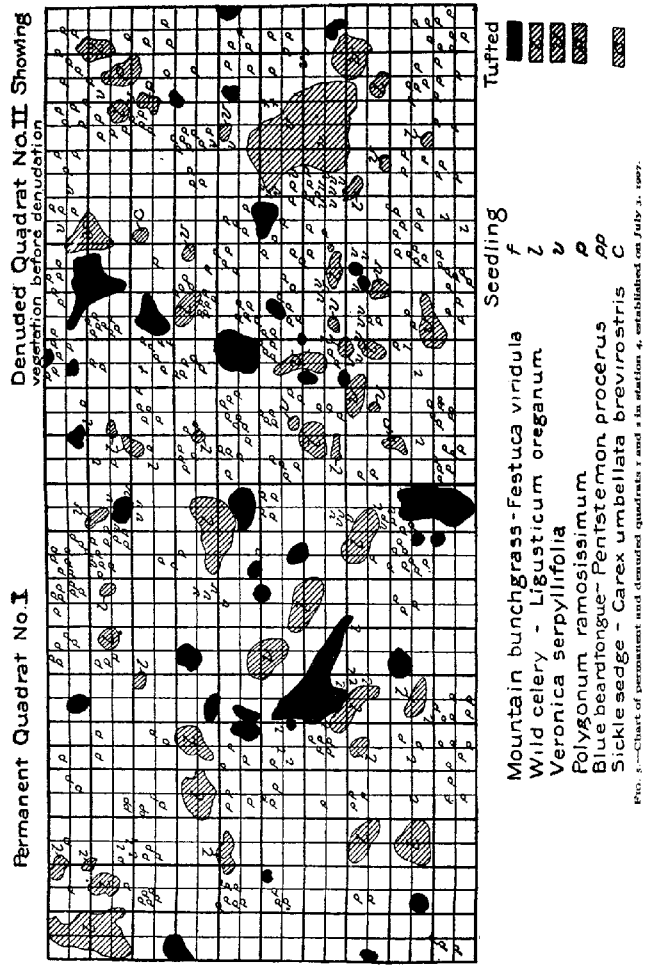

FIG. 5.—Chart of permanent and denuded quadrats 1 and 2 in station 4, established on July 2, 1907.

prior to seed maturity are compared. The leaf blades began to increase in number and length after the first year of protection and continued throughout the four years. The greatest development in the foliage came in the second year of protection, when the plant for the first time

was able to manufacture ample food. Many species of grass had doubled in length by the end of the fourth year.

The increase in actual stand or ground cover was due almost entirely to the enlargement of the tufts, and text figures 5 and 6 show that even under season-long protection the bunch-grasses and other valuable plants

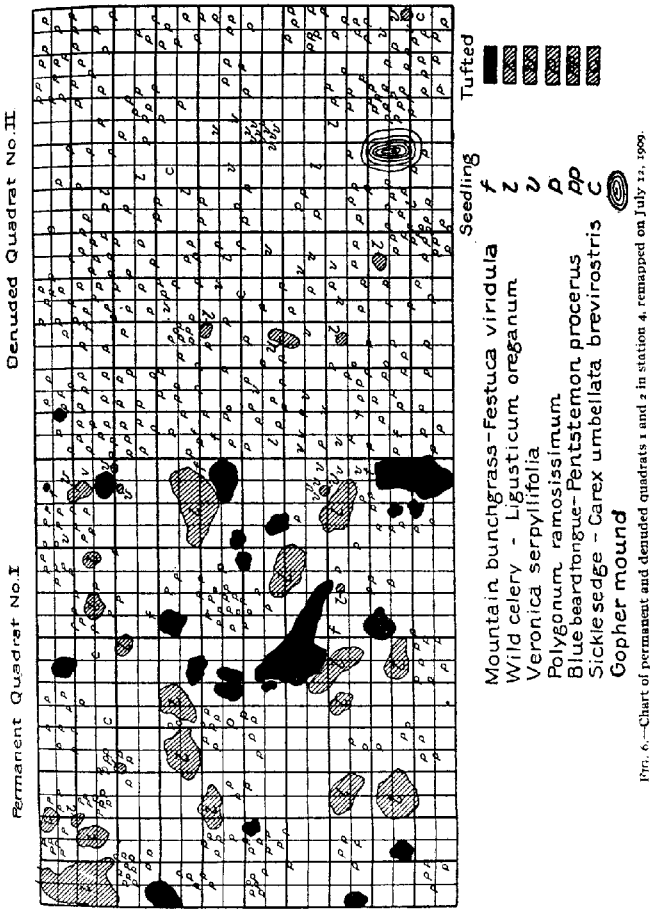

FIG. 6.—Chart of permanent and denuded quadrats 1 and 2 in station 4, remapped on July 12, 1909.

do not increase rapidly by this means. Planimeter measurements of the tufts showed an average increase in diameter of only 18 per cent for the third year of complete protection.

The young, small tufts were the only ones to increase noticeably in size. The tufts of mountain bunch-grass and most tussock-forming

species seldom measure more than 12 inches in diameter, and with the approach toward full development the annual increase becomes less and less. At just what age the hummock or tuft reaches full development is not definitely known, the age doubtless depending upon the species and situation.

TRANSITION ZONE.—Areas were carefully selected and fenced for study in the Transition zone in July, 1907. The range studied had been so seriously depleted that it was difficult to ascertain exactly what plant species constituted the main forage crop. The grasses found in more or less abundance at the time the plats were established were soft cheat, slender hair-grass, Olney's bluegrass, mountain June-grass, pine-grass, big bunch-grass, and western porcupine grass. Other important forage plants occurring sparingly were yarrow, alfileria (*Erodium cicutarium*), arnica (*Arnica cordifolia*), and geranium. Though the ground appeared to be nearly denuded, there was here and there a somewhat conspicuous stand of *Erigeron aureus*, stonecrop (*Sedum douglasii*), *Clarkia pulchella*, and Douglas knotweed (*Polygonum douglasii*).

During the first year of protection there was practically no plant invasion of the permanent quadrats (Pl. XX, fig. 3), but when the fall rains came—about September 1—the early stages of invasion became apparent on denuded areas. The plants to enter first were knotweed, an inconspicuous annual weed, *Clarkia pulchella*, *Erigeron aureus*, alfileria, soft cheat, western porcupine grass, and slender hair-grass, named in the order of their abundance. In the second year practically the same species entered the quadrats, with the addition of a mixed association of three perennial grasses—mountain June-grass, big bunch-grass, and pine-grass. Geranium, arnica, and stonecrop were also noted. At this time soft cheat, an annual species, was the most conspicuous and aggressive.

By the end of the third year, 1909, soft cheat had made such a rank growth that in certain portions of the protected area it had completely replaced the shorter annual weeds (cf. Pls. XX, fig. 3, and XXI, fig. 1). In the denuded quadrats certain perennial species, mountain June-grass, big bunch-grass, Olney's bluegrass, geranium, and yarrow, had also begun to appear as forerunners in the permanent establishment of perennial species. As a result of protection from grazing, the carrying capacity of the protected area as a whole had increased 150 per cent (Pl. XXII). This figure represents the increment in the ground cover within the quadrats rather than the weight of the forage produced. Fully four-fifths of the new growth was composed of annuals, with soft cheat easily predominating. Seeds of this species are small and, like those of western porcupine grass, work their way into the ground by means of special contrivances. The larger and lighter seeds of the perennial plants were found on the surface of the ground at the time of germination, and in consequence practically no seedlings of these species had been established. The perennial species had reproduced vegetatively, but the increase was by no means rapid.

On both the lower and more elevated lands the new forage resulting from yearlong protection consisted almost exclusively of annuals. A very small percentage indeed of the new stand was established through the reproduction of perennial plants. During the first two seasons of protection, even at the lower elevations, the perennials produced practically no fertile seed. In the third season viable seed were produced. The perennial vegetation, which previous to protection from grazing made such a weak growth that its presence was not observed, finally became conspicuous after one or two seasons of rest. Even under the most favorable conditions reproduction by the perennial species is slow, since the seeds are large and unable to work themselves beneath the surface of the soil. The nonuse of the forage under yearlong protection is a serious matter and would have to be considered before this system could be pronounced practicable. Moreover, the accumulation of inflammable material during the period of protection would result in increased fire danger. Under any circumstances it could not be carried out on a large scale without a radical readjustment of the stock industry.

To sum up the facts regarding yearlong protection: The system is not an efficient one, because the most valuable perennial species fail to reproduce by seed. While the carrying capacity of the land is increased, this increase is slow and does not compensate for the waste of the forage crop during the long period necessary for revegetation.

DEFERRED GRAZING

Unlike the two grazing systems just discussed, deferred grazing is based upon the requirements of the vegetation through practically a double life cycle, as defined in the section on the life history of the range plants.

To determine the effect of the deferred grazing system, the vegetation in the different grazing zones was studied for two successive seasons. Convenient areas which had been overgrazed in various degrees and which were large enough to support a band of sheep after the seed had ripened were closed to grazing from the beginning of the season until the seeds of the important species had matured. Upon maturity of the seed crop the range was grazed moderately by a band of sheep during the remainder of the season. The following year the same area was closed to sheep for the same period in order to give the seedlings an opportunity to develop a root system strong enough to withstand trampling and also to permit a second seed crop to be developed and disseminated in case the first year's seeding was unsuccessful. When the area had been satisfactorily reseeded, it was grazed early in the season, and a second area, large enough to maintain a band of sheep from the time of seed maturity to the end of the season, was reserved for deferred grazing. Results of a study to determine the abundance of seedling reproduction under the deferred grazing system, as compared with that under other systems, are shown in Table VII.

TABLE VII.—*Comparative seedling reproduction of perennial forage plants on similar areas under yearlong grazing and deferred grazing—Hudsonian zone*

Character of original vegetation.[a]	Percentage of ground covered by original vegetation.	Character of soil.	Slope and aspect.	Reproduction.					
				Yearlong grazing (1908).			Deferred grazing (1909).		
				Number of unit areas counted.	Total number of seedlings.	Average number of seedlings per square meter.	Number of unit areas counted.	Total number of seedlings.	Average number of seedlings per square meter.
Sickle sedge, yarrow, little needle grass, and western porcupine grass	(b)	Deep clay loam	1° to 2° southwest	17	401	23.6	9	261	29.0
Mountain bunch-grass, big bunch-grass, and little bluegrass	40	Clay loam	3.6° southwest	12	50	4.2	7	220	31.5
Little needle grass and big bunch-grass	20	Gravelly clay loam	5° south	14	49	3.5	10	503	50.3
Little bluegrass and little needle grass	10	do	Level	9	36	4.0	8	337	42.1
Mountain bunch-grass, elk-grass, smooth wild rye, and horsemint	25	Clayey loam	4° to 7° south	11	36	3.3	9	549	61.0
Mountain bunch-grass, onion grass, and little bluegrass	40	Gravelly clay loam	5° east	12	76	6.4	8	386	48.1
Big bunch-grass, western porcupine grass, and sickle sedge	35	do	Level	14	57	4.1	10	219	21.9
Elk-grass, sickle sedge, slender hair-grass, and tufted hair-grass	60	Black loam	2° south	10	113	11.3	6	170	28.3
Average				12.4	101	7.5	8.4	330.6	39.0

[a] Named in the order of its abundance.

[b] Almost denuded.

SEEDLING REPRODUCTION SECURED

It will be seen that as a result of the deferred system of grazing the density of forage seedlings was from 2 to 10 times as great in 1909 as in 1908. Quite as important as the density was the identity of the seedling species. It will be recalled that where yearlong grazing was carried on, seedlings, aside from the annual weeds, consisted of two early-maturing annual plants, sickle sedge and slender hair-grass, together with a more valuable species, western porcupine grass. On the yearlong protected plots practically the only species were the few with small, heavy seeds, and the two porcupine grasses (*Stipa minor* and *S. occidentalis*) which are self-planting. Table VII shows that where deferred grazing was carried out the ground became stocked with seedling plants of all species which produce seed. The most valuable species, mountain bunch-grass, which failed completely under yearlong grazing and yearlong protection, responded exceptionally well. Its seedlings were found in all situations where there were parent plants to produce the necessary seed crop.

In the Canadian zone several of the valuable species which failed to reproduce under either of the other systems regenerated more or less abundantly under deferred grazing.

Although, under deferred grazing, forage seedlings were found wherever there were enough parent plants to produce the necessary seed, the proportion of the seedling stand which ultimately became established depended mainly upon the habitat and climatic conditions, as well as upon sufficient protection from grazing during the period of establishment.

LOSS OF SEEDLING REPRODUCTION BY GRAZING

To determine the extent to which moderate deferred grazing reduces the stand of valuable forage seedlings and whether the subsequent seedling stand resulting from the additional seed crop when thoroughly planted by trampling will offset the number of seedlings lost through grazing, observations were made on selected plots at medium and high elevations. The first observations recorded the character of the vegetation in and around each quadrat for a radius of 10 feet; the density of the herbaceous vegetation within and without the quadrat; the character of the soil and the slope and exposure; and the total number and identity of the seedlings within the quadrat, and their health vigor at the time of observation. With such data it was possible to account for any unusual loss resulting from subsequent grazing. It was recognized, for example, that a seedling, even when deeply rooted, is much more likely to be destroyed by trampling if it is situated on an abrupt hillside, especially in a denuded gravelly soil, than if situated in a level glade between tufts of grass with intertwining roots. Again, a seedling growing under adverse moisture conditions does not develop as elaborate and deep a root system as one which has received enough moisture to furnish the neces-

sary nutrients and so can not withstand as much disturbance of the soil. After the lands had been grazed and sufficient time had been allowed for the vegetation to recover, each quadrat was again observed and notes taken on the total number and identity of the forage seedlings which remained, the number of seedlings found dead, the number unaccounted for, the number whose recovery was doubtful, and the condition of the remaining seedlings at the time of the recounts.

AT MEDIUM ELEVATIONS.—The entire area studied slopes to the west and has a minimum altitude of 5,500 feet and a maximum which brings it into the lower Hudsonian zone. The topography is so irregular and there is so much down timber that the herbage can be grazed only under the most skillful open herding. The lower portion of the range is of the browse type, the much relished Nuttall willow predominating. The undergrowth consists of a host of weedy species, such as fireweed and its associates, with a scattering of smooth wild rye and short-awned brome-grass (Pl. XXIII). At the highest limits of Nuttall willow, seedlings of these species, on account of the shorter growing season, were not developed to the same extent as at the lower altitudes.

The forage stand in existence before and after grazing is shown in Tables VIII and IX.

TABLE VIII.—*Record of native forage seedling stand at medium elevation during the first week in August, preceding grazing*

Quadrat No.[a]	Character of vegetation in and around quadrat within radius of 10 feet.[b]	Density of vegetation.[c] Within quadrat.	Density of vegetation.[c] Without quadrat.	Character of soil.	Slope and exposure.	Total number of seedlings in quadrat.	Number of plants of each seedling species.	Condition of seedlings at time of observations.
1	Smooth wild rye and mountain bunch-grass.	1/10	1/10	Gravelly clay loam	16° west [d]	155	142 smooth wild rye 13 mountain bunch-grass	Good, though a few had died previously.
2	Yarrow, smooth wild rye, valerian, and false hellebore.	2/10	3/10	Clayey loam	20° west	201	193 Smooth wild rye 7 Sickle sedge 1 Elk-grass	Soil dry, seedlings indicating lack of water.
3	Smooth wild rye, skunkweed, valerian, and sickle sedge.	1/10	2/10	do	24° west	43	35 Smooth wild rye 1 Sickle sedge 1 Mountain bunch-grass	Many seedlings found dead, remaining ones showing lack of water.
4	Smooth wild rye, mountain bunch-grass, and valerian.	2/10	2/10	do	18° west	128	105 Smooth wild rye 14 Mountain bunch-grass 6 Sedges	Fair condition.[e]
5	Mountain bunch-grass, smooth wild rye, and lupine.	2/10	5/10	Deep clay loam	18° west	61	52 Smooth wild rye 9 Mountain bunch-grass	Good.
6	Smooth wild rye, lupine, mountain June-grass, valerian, and sickle sedge.	4/10	4/10	do	15° west	93	83 Smooth wild rye 6 Sickle sedge 4 Mountain bunch-grass	Do.
7	Short-awned brome-grass, smooth wild rye, and false hellebore.	5/10	5/10	Shallow, gravelly clay	14° west	112	92 Short-awned brome-grass 19 Smooth wild rye 2 Sickle sedge	Do.
8	Short-awned brome-grass, mountain June-grass, and skunkweed	4/10	4/10	Clay loam heavily impregnated with decaying wood.	12° west	80	64 Short-awned brome-grass 16 Smooth wild rye	Do.[e]
9	Smooth wild rye and valerian	1/10	4/10	Gravelly loam	26° southwest	84	51 Smooth wild rye 1 Sickle sedge 1 Mountain bunch-grass 1 Elk-grass	Suffering from drought.
10	Smooth wild rye, elk-grass, and false hellebore.	1/10	1/10	do	18° west	60	53 Smooth wild rye 6 Elk-grass 1 Sickle sedge	Good.
11	Smooth wild rye, valerian, and yarrow.	6/10	5/10	Clay loam	22° west	94	89 Smooth wild rye 5 Sickle sedge	Seedlings wilting, tips of leaf blades dead.
12	Smooth wild rye, false hellebore, and yarrow.	1/10	2/10	Slightly granitic clay loam.	26° west	66	58 Smooth wild rye 6 Sickle sedge 1 Mountain bunch-grass 1 Elk-grass	Do.

[a] These quadrats were remapped subsequent to grazing, the results of which appear in Table IX.
[b] Only the most predominant species are recorded under this heading. The species are arranged in the order of their abundance, the most predominant being given first.
[c] To represent the density of growth 10 is taken as complete ground cover.
[d] Situated on old sheep path.
[e] Gullying of the soil exposed the roots of a few seedlings.

TABLE VIII.—*Record of native forage seedling stand at medium elevation during the first week in August, preceding grazing*—Continued

Quadrat No.	Character of vegetation in and around quadrat within radius of 10 feet.	Density of vegetation.		Character of soil.	Slope and exposure.	Total number of seedlings in quadrat.	Number of plants of each seedling species.	Condition of seedlings at time of observations.
		Within quadrat.	Without quadrat.					
13	Smooth wild rye and short-awned brome-grass.	2/10	4/10	Black clay loam	16° west	199	178 Smooth wild rye. 19 Short-awned brome-grass. 2 Sickle sedge	Fair, competition between rye-grass seedlings somewhat severe.
14	Smooth wild rye, western porcupine grass, lupine, and valerian.	5/10	1/10	....do	15° west	45	42 Smooth wild rye. 3 Western porcupine grass	Good.
15	Smooth wild rye and false hellebore.	5/10	3/10	Deep clay loam	14° west [a]	105	101 Smooth wild rye. 4 Short-awned brome-grass	Do.
	Average					100.8		

[a] Situated on old sheep path.

TABLE IX.—*Record of native forage seedling stand at medium elevation during the first week in September, after grazing*

Quadrat No.	Total number of seedlings remaining.	Total loss.	Percentage lost.	Number actually found dead.	Number not accounted for.	Number of plants of remaining seedling species.	Total number whose recovery is doubtful.[a]	Condition of remaining seedling stand at time of recount.	Remarks.
1	66	73	47.1	7	60	62 Smooth wild rye 4 Mountain bunch-grass	3	All native forage eaten closely in quadrat, leaving many roots exposed.	
2	98	103	51.2	11	90	92 Smooth wild rye 4 Sickle sedge 2 Elk grass	2	Sheep trail through part of quadrat, destroying and weakening many seedlings.	Sheep trail a foot wide and 4 inches deep.
3	12	31	72.1	3	27	10 Smooth wild rye 1 Sickle sedge 1 Mountain bunch-grass	1	Forage closely grazed and trampled	All vegetation eaten into the ground.
4	54	71	56.8	8	60	34 Smooth wild rye 6 Mountain bunch-grass 4 Sedge	3	Trail through quadrat destroyed and weakened all seedlings in its path.	Many roots of seedlings exposed, due to soil washing.
5	28	33	54.1	5	27	26 Smooth wild rye 2 Mountain bunch-grass	1	Moderately grazed; seedlings in good condition.	
6	30	63	67.7	13	49	26 Smooth wild rye 4 Sickle sedge	1	Badly trampled; many seedling roots exposed.	
7	67	45	40.2	11	31	61 Short-awned brome-grass 6 Smooth wild rye	3	Closely grazed, but seedlings in good condition.	
8	74	7	8.6	4	0	68 Short-awned brome-grass 6 Smooth wild rye	3	Grazed very moderately; seedlings not injured.	Quadrat not in open, exposed position.
9	31	23	42.6	3	15	29 Smooth wild rye 1 Mountain bunch-grass 1 Elk grass	5	Grazed closely; seedlings in fair condition.	
10	31	29	48.3	3	22	28 Smooth wild rye 3 Elk grass	4	Moderately grazed; seedlings vigorous.	
11	46	48	51.0	7	39	44 Smooth wild rye. 2 Sickle sedge.	2	Very closely grazed and badly trampled; seedlings rather weak.	On open grazing land.
12	29	37	56.0	6	25	28 Smooth wild rye 1 Sickle sedge	6	Moderately grazed; seedlings vigorous.	
13	77	121	61.1	15	106	75 Smooth wild rye 2 Short-awned brome-grass	0	do	
14	22	23	51.1	3	12	19 Smooth wild rye 2 Short-awned brome-grass 1 Mountain bunch-grass	8	Badly trailed and trampled; seedlings fairly strong.	No seedlings left in trail.
15	47	58	55.2	12	40	46 Smooth wild rye 1 Short-awned brome-grass	6	do	Do.
Average.	48.5	50	50.9						

[a] Of the seedlings whose recovery from grazing or drought was doubtful, none were included in the number composing the "total number of seedlings remaining," as shown in column 2 of this table.

In Table VIII it will be seen that the seedling stand before grazing was rather dense, the average for all quadrats being 100.8 per square meter. Fortunately the less valuable species, such as sickle sedge, were the ones most weakened by drought, their condition, as will be noted, corresponding closely with the character of the soil, the more porous types supporting the less vigorous plants.

After grazing (Table IX) the average stand was reduced to 48.5 per square meter, a loss of 50.9 per cent. The heaviest loss was at the upper limit of the area, where the short growing season caused the seedlings to be less deeply rooted. At the lower elevations the heaviest loss was where the young plants were cropped. Many of the lateral roots were pulled out or broken, and death followed.

On account of the rather severe and uneven grazing, it was practically impossible to determine definitely what species were best able to withstand trampling. An examination of the root systems showed that smooth wild rye had almost invariably pushed its roots more deeply into the soil than any other species. Short-awned brome-grass also develops an unusually strong, deep, and spreading root, and showed ability to withstand trampling and to recover its vigor when portions of the root were pruned off below the surface, or even when segments of the rootlets were exposed to the air. Seedlings of mountain bunch-grass also withstood trampling comparatively well, notwithstanding the fact that at the time the range was cropped it was not so far advanced as the other species.

At High Elevation.—Owing to a great variety of conditions at the high elevations, 62 quadrats were established late in August before grazing. The range, which has a minimum altitude of approximately 7,500 feet, is distinctly herbaceous, the growth consisting primarily of grasses, with mountain bunch-grass and western porcupine grass predominating in the order named. (See text fig. 5.) In addition, there are several species of sedges and rushes, with a sprinkling of weeds and non-grasslike plants, especially in the moister situations.

At the time of the first observations nearly all the seedlings were in good condition, though dead individuals were often found in the drier situations. In other cases the terminal portions of some of the leaf blades were dead, but this did not necessarily indicate a weakened condition of the plant. The seedling stand, before and after grazing, is shown in Tables X and XI.

TABLE X.—*Record of native forage seedling stand at high elevations after August 15, preceding grazing*

Quadrat No.	Character of vegetation in and around quadrat within radius of 10 feet.[b]	Density of vegetation.[a] Within quadrat.	Density of vegetation.[a] Outside quadrat.	Character of soil.	Slope and exposure.	Total number of seedlings in quadrat.	Number of plants of each seedling species.	Condition of seedlings at time of observation.
1	Mountain bunch-grass and sickle sedge.	4/10	3/10	Coarse gravelly loam	15° west	194	193 Mountain bunch-grass... 1 Sickle sedge	Good.
2	do	2/10	1/10	Clay loam with some gravel.[c]	25° west	277	277 Mountain bunch-grass...	Some showed effects of drought.[c]
3	Mountain bunch-grass, sickle sedge, and western porcupine grass.	1/10	Denuded.	do	do	152	149 Mountain bunch-grass... 2 Western porcupine grass 1 Sickle sedge	Do.
4	do	5/10	do	Clay loam	16° west	43	43 Mountain bunch-grass...	Good.
5	do	4/10	5/10	Gravelly clay loam	18° west	572	560 Mountain bunch-grass... Elk-grass	Fair, but competition had restricted their growth.
6	Mountain bunch-grass, little bluegrass, and sickle sedge.	3/10	1/10	Deep loam rich in organic matter.	13° south	295	295 Mountain bunch-grass...	Fair; about 1/10 stand dead.
7	do	2/10	1/10	Clay loam	14° south	140	137 Mountain bunch-grass... 3 Sickle sedge	Good.
8	Mountain bunch-grass	3/10	5/10	Gravelly clay loam	20° west	379	379 Mountain bunch-grass...	Portions of quadrat contained too dense growth for best development.
9	do	1/10	Denuded.	Very coarse gravelly loam.	do	193	193 Mountain bunch-grass...	Fair; some of terminal leaf blades dead.
10	Mountain bunch-grass, western porcupine grass, and sickle sedge.	5/10	do	do	10° west	320	310 Mountain bunch-grass... 5 Western porcupine grass 5 Sickle sedge	Vigorous.
11	Mountain bunch-grass and wild buckwheat.	3/10	1/10	Clay loam	22° west	214	212 Mountain bunch-grass... 2 Sickle sedge	Fair; many seedlings had previously died.[d]
12	Mountain bunch-grass	3/10	2/10	Gravelly loam	18° west	152	149 Mountain bunch-grass... 3 Sickle sedge	Good.
13	Mountain bunch-grass and sickle sedge.	5/10	5/10	Clay loam	16° west	96	93 Mountain bunch-grass... 2 Sickle sedge 1 Sedge	Thrifty.
14	do	1/10	3/10	Gravelly clay loam	28.5° west	172	171 Mountain bunch-grass... 1 Sickle sedge	Rather poor for lack of water.[e]

[a] To represent the density of growth, 10 is taken as complete ground cover.
[b] Only the most predominant species are recorded. They are arranged in their order of abundance.
[c] Soil lacking in organic matter.
[d] Soil had washed slightly.
[e] Gullying had been rather severe surrounding quadrat.

TABLE X.—*Record of native forage seedling stand at high elevation after August 15, preceding grazing*—Continued

Quadrat No.	Character of vegetation in and around quadrat within radius of 10 feet.	Density of vegetation. Within quadrat.	Density of vegetation. Outside quadrat.	Character of soil.	Slope and exposure.	Total number of seedlings in quadrat.	Number of plants of each seedling species.	Condition of seedlings at time of observation.
15	Western porcupine grass, mountain bunch-grass, and sickle sedge.	Denuded.	2/10	Gravelly clay loam	10° west	90	85 Western porcupine grass 5 Sickle sedge	Vigorous.
16	Western porcupine grass, mountain bunch-grass, yarrow, and wild buckwheat.	3/10	5/10	Clay loam with little gravel.	3° south	130	121 Western porcupine grass 9 Yarrow	Do.
17	Mountain bunch-grass, western porcupine grass, and sickle sedge.	5/10	4/10	Clay loam	3° southwest	243	240 Western porcupine grass 2 Yarrow 1 Sickle sedge	Fair.
18	Western porcupine grass and mountain bunch-grass.	6/10	6/10	Clay loam	4° south	228	222 Western porcupine grass. 4 Sickle sedge 2 Mountain bunch-grass	Vigorous.
19	do		1/10	3/10	Fine clay loam	5° southwest	295	267 Western porcupine grass. 27 Mountain bunch-grass 1 Sickle sedge
20	Western porcupine grass, yarrow, and mountain bunch-grass.	2/10	3/10	Very coarse, gravelly loam.	4° south	172	169 Western porcupine grass 3 Mountain bunch-grass	Medium.
21	Western porcupine grass, mountain bunch-grass, and blue beardtongue.	1/10	2/10	Clay loam	5° southwest	52	52 Western porcupine grass.	Exceptionally vigorous.
22	Western porcupine grass, mountain bunch-grass, yarrow, and alum-root.	5/10	3/10	Coarse gravelly loam	3° south	320	312 Western porcupine grass. 6 Mountain bunch-grass 2 Sickle sedge	Competition too strong; many very weak.[a]
23	Western porcupine grass, mountain bunch-grass, and blue beardtongue.	5/10	1/10	Gravelly clay loam	4° south	169	166 Western porcupine grass. 2 Mountain bunch-grass 1 Sickle sedge	Good; above average.
24	Mountain bunch-grass, western porcupine grass, and yarrow.	5/10	1/10	do	1° south	218	195 Western porcupine grass. 21 Mountain bunch-grass 2 Sickle sedge	Good.
25	Western porcupine grass, mountain bunch-grass, and yarrow.	3/10	2/10	Very light gravelly loam.	4° south	145	129 Western porcupine grass. 13 Mountain bunch-grass 3 Elk-grass	Fair; some partly died back.
26	Mountain bunch-grass, western porcupine grass, and white foxtail.	1/10	1/10	Very coarse, gravelly clay loam.	4° east	52	27 Mountain bunch-grass 23 Western porcupine grass. 2 Sickle sedge	Some of mountain bunch-grass seedlings not vigorous.

27	Mountain bunch-grass, western porcupine grass, and blue beardtongue.	Denuded.	4/10	Light clay loam	3° southeast	103	81 Mountain bunch-grass 17 Western porcupine grass. 5 Sedges	Good.
28	Mountain bunch-grass and sickle sedge.	1/10	2/10	Scab and coarse gravelly loam.	4° east	32	24 Mountain bunch-grass 4 Sickle sedge 4 Western porcupine grass	Do.
29	Mountain bunch-grass and western porcupine grass.	5/10	5/10	Clay loam	10° south	145	71 Western porcupine grass. 68 Mountain bunch-grass 6 Sickle sedge	Vigorous.
30	Western porcupine grass, mountain bunch-grass, and wild buckwheat.	5/10	2/10	Very coarse gravelly loam.	5° southeast	278	254 Western porcupine grass. 19 Mountain bunch-grass 5 Short-awned brome-grass.	Medium.
31	Western porcupine grass and mountain bunch-grass.	Denuded.	3/10	Coarse gravelly clay loam.	11° southeast	486	417 Western porcupine grass. 68 Mountain bunch-grass 1 Elk-grass	Medium; seedlings too thick in places.[b]
32	Short-awned brome-grass, western porcupine grass, mountain bunch-grass, and wild buckwheat.	2/10	3/10	do	6° east	66	51 Short-awned brome-grass. 6 Western porcupine grass. 5 Sickle sedge 4 Mountain bunch-grass	Excellent.
33	Mountain bunch-grass and western porcupine grass.	1/10	2/10	do	9° south	88	83 Western porcupine grass. 4 Mountain bunch-grass 1 Sickle sedge	Medium; some show severe effects from drought.
34	Mountain bunch-grass, smooth wild rye, and western porcupine grass.	1/10	6/10	Scabby, gravelly loam	2° southeast	54	42 Smooth wild rye 6 Western porcupine grass 3 Mountain bunch-grass 3 Sickle sedge	Rye-grass seedlings so tall as to furnish forage.
35	Smooth wild rye, western porcupine grass, and mountain bunch-grass.	1/10	5/10	Gravelly loam	12° south	73	46 Smooth wild rye 25 Western porcupine grass. 2 Sickle sedge	Good.
36	Mountain bunch-grass, western porcupine grass, and smooth wild rye.	2/10	4/10	Coarse, gravelly clay loam.	12° southeast	101	81 Smooth wild rye 9 Western porcupine grass. 7 Mountain bunch-grass 4 Sickle sedge	Medium.
37	Western porcupine grass, mountain bunch-grass, smooth wild rye, and sickle sedge.	1/10	5/10	Rocky "scabland," with shallow loam.	10° south	246	220 Western porcupine grass. 14 Mountain bunch-grass 10 Sickle sedge 2 Smooth wild rye	Vigorous.
38	Smooth wild rye and little bluegrass.	(c)	2/10	do	4° southeast	37	31 Smooth wild rye 3 Little bluegrass 3 Yarrow	Vigorous; little bluegrass somewhat weak.
39	Western porcupine grass, mountain bunch-grass, and yarrow.	3/10	2/10	Very coarse gravelly loam.	14° south	217	213 Western porcupine grass. 3 Mountain bunch-grass 1 Yarrow	Good; have made exceptional growth.
40	Little bluegrass, big bunch-grass and slender hair-grass.	1/10	4/10	Fine, gravelly clay loam.[d]	Level	135	120 Little bluegrass 12 Slender hair-grass 1 Smooth wild rye 1 Yarrow 1 Big bunch-grass	Drought has weakened many.

[a] Soil had washed slightly; seedlings too thick.
[b] Root competition severe in some parts of quadrat.
[c] Nothing but seedlings.
[d] Soil compact and somewhat baked.

TABLE X.—*Record of native forage seedling stand at high elevation after August 15, preceding grazing*—Continued

Quadrat No.	Character of vegetation in and around quadrat within radius of 10 feet.	Density of vegetation. Within quadrat.	Density of vegetation. Outside quadrat.	Character of soil.	Slope and exposure.	Total number of seedlings in quadrat.	Number of plants of each seedling species.	Condition of seedlings at time of observation.
41	Western porcupine grass, small bluegrass, mountain bunch-grass, and blue beardtongue.	Denuded.		Clay loam	12.5° south	78	62 Porcupine grass 7 Little bluegrass 5 Blue foxglove 3 Smooth wild rye 1 Yarrow	Good.
42	Little bluegrass, short-awned brome-grass, and mountain bunch-grass.	1/10	3/10	Clay loam	11.5° south	185	148 Little bluegrass 13 Yarrow 11 Short-awned brome-grass. 10 Smooth wild rye 3 Mountain bunch-grass	Little bluegrass; poor for lack of water.
43	Mountain bunch-grass, western porcupine grass, and sickle sedge.	2/10	4/10	Gravelly clay loam	14° south	94	81 Western porcupine grass. 5 Little bluegrass 5 Sickle sedge 3 Mountain bunch-grass	Medium.
44	Smooth wild rye, yarrow, and mountain dandelion.	5/10	2/10	Clay loam	4° south	204	180 Smooth wild rye 13 Mountain dandelion 11 Yarrow	Do.
45	Western porcupine grass, mountain bunch-grass, and blue beardtongue.	Denuded.	5/10	Scabby soil, shallow loam.	9° west	321	321 Western porcupine grass.	Rather badly wilted.
46	Mountain bunch-grass, little bluegrass, yarrow, and blue beardtongue.	1/10	4/10	Clay loam[a]	3° south	74	57 Mountain bunch-grass 13 Mountain dandelion 3 Yarrow 1 Blue beardtongue	Fair; some roots gullied out of ground.
47	Western porcupine grass, smooth wild rye, and mountain bunch-grass.	1/10	4/10	Gravelly clay loam	12° south	87	61 Western porcupine grass. 23 Alpine redtop 3 Smooth wild rye	Very good.
48	Mountain bunch-grass, western porcupine grass, and big bunch-grass.	1/10	2/10	Very coarse, gravelly clay loam.	3° south	36	28 Mountain bunch-grass. 5 Yarrow 2 Big bunch-grass 1 Smooth wild rye	Do.
49	Western porcupine grass, mountain bunch-grass, smooth wild rye, and yarrow.	1/10	6/10	Gravelly clay loam	9° south	287	274 Western porcupine grass. 9 Yarrow 4 Mountain bunch-grass	Good.

50	Smooth wild rye, mountain bunch-grass, and yarrow.	1/10	6/10	do	1° south	67	49 Smooth wild rye 16 Yarrow 2 Mountain bunch-grass	67	Do.
51	Western porcupine grass, mountain bunch-grass, and yarrow.	1/10	1/10	Rocky gravelly loam	13° south	166	142 Western porcupine grass. 18 Mountain bunch-grass. 6 Sickle sedge	166	Medium. Many had previously died.
52	Mountain bunch-grass and a number of annual weeds.	1/10	3/10	do	8° south	24	24 Mountain bunch-grass	24	Generally good.
53	Mountain bunch-grass and yarrow.	2. 5/10	2, 10	Scabby clay loam	13° east	39	34 Mountain bunch-grass. 5 Sickle sedge.	39	Medium.
54	Mountain bunch-grass and western porcupine grass.	1/10	3/10	do	4° east	36	30 Mountain bunch-grass. 5 Western porcupine grass. 1 Sedge	36	Excellent.
55	Western porcupine grass and annual weeds.	4/10	2/10	Rocky clay loam [b]	10° east	321	321 Western porcupine grass.	321	Very poor, 50 per cent having previously died.
56	Mountain bunch-grass, western porcupine grass, and short-awned brome-grass.	2/10	3/10	Rocky, gravelly clay loam.	3° east	33	28 Mountain bunch-grass. 3 Western porcupine grass. 2 Short-awned brome-grass	33	Good.
57	Mountain bunch-grass	5/10	5/10	Clay loam	9° east	32	32 Mountain bunch-grass	32	Vigorous.
58	Mountain bunch-grass and western porcupine grass.	2/10	1/10	Rocky clay loam	5° east	45	40 Mountain bunch-grass. 5 Western porcupine grass.	45	Good.
59	Mountain bunch-grass and western porcupine grass.	2. 6/10	2/10	Clay loam	22° east	27	17 Mountain bunch-grass. 9 Western porcupine grass. 1 Sickle sedge	27	Medium.
60	Mountain bunch-grass	2/10	1/10	Deep clay loam [c]	6° east	30	29 Mountain bunch-grass. 1 Western porcupine grass.	30	Vigorous; unusually large.
61	do	1/10	1/10	do	7° east	29	29 Mountain bunch-grass	29	Vigorous.
62	Mountain bunch-grass and western porcupine grass.	1/10	2/10	Gravelly clay	8° east	35	34 Mountain bunch-grass. 1 Western porcupine grass.	35	Good.
	Average seedling stand					155.3			

[a] Surface soil removed by washing to depth of 2 inches.
[b] Soil very dry; terminal part of many leaf blades dead.
[c] Soil very compact and slightly baked.

TABLE XI.—*Record of native forage seedling stand at high elevations after September 1, after grazing*

Quadrat No.	Total number of seedlings remaining.	Total loss.	Percentage lost.	Number found dead.	Number not accounted for.	Number of plants of remaining seedling species.	Number whose recovery seemed doubtful.[a]	Condition of remaining seedling stand at time of recount.	Remarks.
1	119	75	38.6	6	69	119 Mountain bunch-grass	3	Much weakened through close grazing and trailing.	
2	162	115	41.5	10	105	162 Mountain bunch-grass	6	do	
3	81	71	46.7	3	68	80 Mountain bunch-grass 1 Western porcupine grass		Fair; showed lack of moisture.	
4	26	17	39.5	2	15	26 Mountain bunch-grass	1	Medium strong	
5	248	324	56.6	15	309	244 Mountain bunch-grass 4 Elk-grass	21	Medium; closely grazed	Drought had previously impaired the seedling growth.
6	122	173	58.6	5	168	122 Mountain bunch-grass	33	Vigorous	
7	54	86	61.4	7	89	53 Mountain bunch-grass 1 Sickle sedge	5	Generally strong, some much weakened.	
8	183	196	51.7	23	173	183 Mountain bunch-grass	11	Fair	Severely grazed.
9	98	87	47.5	2	85	96 Mountain bunch-grass	8	Fair; seedlings previously weakened for lack of water.	
10	147	173	54.0	6	167	145 Mountain bunch-grass 1 Western porcupine grass 1 Sickle sedge	7	Fair	
11	94	120	56.0	10	110	103 Mountain bunch-grass 1 Sickle sedge	4	Terminal part of some leaf blades dead.	Washing of soil had exposed some of the seedling roots.
12	89	53	41.4	4	59	89 Mountain bunch-grass	5	Thrifty	
13	59	37	38.5	2	35	58 Mountain bunch-grass 1 Sickle sedge	2	Seedlings much weakened for lack of water.	
14	116	56	32.5	4	52	116 Mountain bunch-grass	4	Vigorous	
15	45	45	50.0		45	44 Western porcupine grass 1 Sickle sedge	4	do	
16	68	62	47.7	12	50	61 Western porcupine grass 7 Yarrow	6	Medium strong	Weakness of seedlings due, in part, to poor moisture conditions.
17	107	136	55.9	3	133	105 Western porcupine grass 2 Yarrow		Vigorous	
18	145	83	36.4	11	72	140 Western porcupine grass 2 Mountain bunch-grass 3 Sickle sedge	5	do	
19	123	172	58.3	2	170	122 Western porcupine grass 1 Sickle sedge		Most of seedlings weak	
20	96	76	44.2	13	63	95 Western porcupine grass 1 Mountain bunch-grass	7	Fair; poor soil and drought the main cause.	
21	30	22	42.3	8	14	30 Western porcupine grass	4	Vigorous	

22	204	116	36.2	4	112	198 Western porcupine grass 6 Mountain bunch-grass	4	Weakened badly by trampling.	Many roots exposed because of trampling and close seedling stand.
23	101	68	40.2	9	59	100 Western porcupine grass 1 Sickle sedge	1	Medium vigorous	
24	117	101	46.3	3	98	111 Western porcupine grass 6 Mountain bunch-grass	3	Good	
25	69	76	52.4	2	74	60 Western porcupine grass 7 Mountain bunch-grass 2 Sickle sedge	7	Fair; closely grazed	
26	17	35	67.3	3	32	9 Western porcupine grass 8 Mountain bunch-grass	3	Poor	Sheep had trailed through quadrat, destroying many seedlings.
27	30	73	70.8	6	67	29 Mountain bunch-grass 1 Western porcupine grass 8 Mountain bunch-grass	2	Good	
28	14	18	56.2	4	14	5 Western porcupine grass 1 Sickle sedge	4	Much weakened	
29	72	73	50.3	2	71	50 Western porcupine grass 20 Mountain bunch-grass 2 Sickle sedge	1	Severely trampled and weakened.	
30	140	139	49.8	3	136	132 Western porcupine grass 5 Mountain bunch-grass 3 Short-awned brome-grass	3	Vigorous	
31	133	353	72.6	11	342	116 Western porcupine grass 17 Mountain bunch-grass	4	Severely trampled; quadrat on public sheep trail.	Seedlings previously weakened through competition and drought.
32	34	32	48.4	3	29	20 Short-awned brome-grass 3 Western porcupine grass 1 Mountain bunch-grass	3	Vigorous	
33	60	28	31.8	6	22	59 Western porcupine grass 1 Mountain bunch-grass	1	....do	
34	45	9	16.6	7	2	40 Smooth wild rye 3 Mountain bunch-grass 2 Western porcupine grass	8	Smooth wild rye has made unusual height growth. Vigorous.	Had escaped close grazing.
35	37	36	49.3	1	35	30 Smooth wild rye 7 Western porcupine grass	3	Fair; showed effects of trampling.	
36	66	35	34.6	11	24	61 Smooth wild rye 3 Western porcupine grass 2 Mountain bunch-grass	7	Good	
37	92	154	62.6	5	149	144 Western porcupine grass 4 Mountain bunch-grass 1 Sickle sedge	4	Many seedlings eaten off and partly pulled out of ground.	
38	29	8	21.6	4	4	27 Smooth wild rye 2 Little bluegrass		Medium strong	
39	137	80	36.8		80	134 Western porcupine grass 3 Mountain bunch-grass		Vigorous	

a Of the seedlings whose recovery from grazing, drought, or other causes was doubtful, none were included in the number composing the "total number of seedlings remaining," as shown in column 2 of this table.

TABLE XI.—*Record of native forage seedling stand at high elevations after September 1, after grazing*—Continued

Quadrat No.	Total number of seedlings remaining.	Total loss.	Percentage lost.	Number found dead.	Number not accounted for.	Number of plants of remaining seedling species.	Number whose recovery seemed doubtful.	Condition of remaining seedling stand at time of recount.	Remarks.
40	118	17	12.5	4	13	112 Little bluegrass 5 Slender hair-grass 1 Yarrow	14	A few weak, most of them vigorous.	Greatest injury to seedlings due to early drought period.
41	45	33	42.3	7	26	31 Western porcupine grass 7 Little bluegrass 4 Blue beardtongue 3 Smooth wild rye	5	Vigorous; had produced unusual growth in height.	
42	155	30	16.2	18	12	138 Little bluegrass 9 Smooth wild rye 6 Yarrow 2 Mountain bunch-grass	8	Vigorous	
43	70	24	25.5	3	21	57 Western porcupine grass 5 Little bluegrass 5 Sickle sedge 3 Mountain bunch-grass		A few doubtful of recovery; others vigorous.	
44	148	56	27.4	15	41	128 Smooth wild rye 11 Yarrow 9 Mountain dandelion	2	Vigorous	
45	171	150	46.7	12	137	171 Western porcupine grass 9 Mountain bunch-grass		Good	
46	20	54	72.9	4	50	7 Mountain dandelion 4 Yarrow	4	Medium	Seedlings weakened through the gullying of the soil.
47	51	38	42.7	4	34	44 Western porcupine grass 6 Alpine redtop 1 Smooth wild rye	6	Vigorous	
48	31	3	8.8		3	29 Mountain bunch-grass 2 Yarrow	6	.....do	
49	165	122	42.5	6	116	163 Western porcupine grass 2 Yarrow	4	.....do	
50	44	23	34.3	2	22	29 Smooth wild rye 14 Yarrow 1 Mountain bunch-grass	2	.....do	Some seedlings destroyed by gopher mounds.
51	41	124	74.7		124	36 Western porcupine grass 5 Mountain bunch-grass	10	Medium	Sheep trail through quadrat responsible for heavy loss.
52	13	11	45.8	8	3	13 Mountain bunch-grass	1	Vigorous	
53	23	16	41.0	4	12	21 Mountain bunch-grass 2 Sickle sedge		Medium; showed effects of drought.	
54	5	31	86.1		31	4 Mountain bunch-grass 1 Sickle sedge		Excellent	

55	61	230	71.0	18	[illegible]	61 Western porcupine grass	1	Very poor	Drought had severely weakened seedlings early in season.
56	15	18	54.5	2	16	13 Mountain bunch-grass 2 Western porcupine grass		Good	
57	9	23	7[illegible].8	2	21	9 Mountain bunch-grass		Vigorous	
58	14	31	68.8	3	28	10 Mountain bunch-grass 4 Western porcupine grass		do	
59	10	17	62.9	[illegible]	15	7 Mountain bunch-grass 2 Western porcupine grass 1 Sickle sedge	1	Medium strong	
60	17	13	43.3		13	17 Mountain bunch-grass	1	Vigorous	Soil firm and remaining seedlings little injured by trampling.
61	18	11	37.9	4	7	18 Mountain bunch-grass	3	Vigorous; have made unusual growth in height.	
62	11	24	68.5	3	21	11 Mountain bunch-grass		Vigorous	Narrow trail made through quadrat, killing all seedlings in its path.
Average	80.5	74.5	48.2						

It will be seen that both before and after grazing the more abundant seedlings were of mountain bunch-grass, smooth wild rye, short-awned brome-grass, sickle sedge, little bluegrass, and western porcupine grass. Table X shows that before grazing there was an average for all quadrats of 155.3 seedlings per square meter. After grazing (Table XI) this was reduced to 80.5 seedlings, a loss of 48.2 per cent. A comparison of the height and root development of the same seedling species at medium and high elevations discloses the fact that the shorter and later growing season of the high range had not been conducive to the rapid development made by the seedlings in the lower and warmer, though drier, situations. Though the high ranges were grazed much more moderately, the loss was practically the same as on the lower ones.

The factors responsible for the heaviest loss of seedlings through grazing were (1) superabundance of soil moisture, (2) lack of soil moisture, (3) abnormally dense seedling stands, and (4) irregular topography.

In wet situations the roots did not penetrate as deeply as in the more compact and drier soils, and so were more easily disturbed. Although in some cases the seedlings recovered, the loss on the moist soils was relatively large, in fact occasionally five times that on the dry soils.

In excessively dry situations the loss from grazing was often serious, owing to the relatively weak growth made by the seedlings and their poor recuperative power. In some places practically the entire seedling stand was destroyed. Doubtless many of the seedlings whose destruction was charged to grazing would have perished in any event from drought, though the stand as a whole was not affected by this factor. The lack of vigor in individual plants where the stand was unusually dense often caused a heavy loss. Quadrats with from 250 to 500 seedlings almost invariably suffered more than the contiguous plots which carried a sparser stand. In general, it may be said that more than 200 seedlings to a square meter is a heavier stand than most situations can support permanently. Competition is most severe between plants of the same species, since each plant makes the same demand upon the habitat. Where a dense stand occurred it was usually of a single species.

The loss from trampling was much more severe on steep slopes than on level situations. This was largely the result of the coarser texture of the soils on steep slopes and of the greater extent to which they are shifted by grazing. Moreover, because of the lack of soil moisture on many of the steeper slopes, the plants growing there are generally less vigorous than those growing in more level places.

TIME AND INTENSITY OF GRAZING AFTER THE FIRST YEAR

Though the information here presented shows that the range upon which deferred grazing was practiced suffered heavy loss of seedlings when moderately grazed, it should not be concluded that in order to

insure permanent improvement grazing must be suspended from the time the first seed crop is produced until the seedlings become established. Notwithstanding the fact that half the stand in existence in the autumn is likely to be eliminated by grazing, the planting of an additional seed crop will, as a rule, fully offset this loss.

The time at which the seed crop of the established vegetation reaches maturity, marking the approximate limit of growth and occurring in the region studied about September 1, is the beginning of the period when the range may be grazed with the least injury to forage seedlings. During the four weeks prior to this period the root system almost doubles its growth and strength.

On account of the much more elaborately developed root system at the end of the second year of the seedlings' growth, the loss through grazing at that period perceptibly lessens. Even then, however, the range should not be grazed prior to the maturity of the seed crop. Restriction of grazing to the period following seed maturity will give both the 1- and 2-year-old plants sufficient protection to insure the restocking of the range.

To sum up the conclusions regarding deferred grazing, it may be said that the system has proved highly successful wherever an adequate seed crop was produced. Its advantages over yearlong grazing and yearlong protection are (1) the restoration and maintenance of the vegetation without the loss of the forage crop in any year, (2) the planting of the seed, and (3) the removal of the vegetation itself, thus minimizing the fire danger from an accumulation of inflammable material.

Deferred grazing has all the advantages of complete protection, so far as the rejuvenation of the weakened plants is concerned; and, if overstocking and abusive management are guarded against, the system will work no material injury to forest reproduction or watersheds. It is believed, therefore, that the principles of deferred grazing, with whatever modifications are necessary to meet local conditions, should be applied to the management of all ranges.

APPLICATION OF DEFERRED GRAZING SYSTEM TO RANGE MANAGEMENT

WHERE APPLICABLE

If grazing lands are to be fully revegetated within a reasonable time, the range lands must, of course, support at the outset at least a sparse stand of the species valuable for grazing and revegetation purposes. In the Wallowa Mountains, where mountain bunch-grass constitutes the predominating herbage, a satisfactory seed crop and subsequent seedling stand were secured where the original tussocks stood as far apart as 6 feet. Where grazing has been so severe as to destroy the major portion of the original vegetation, the remaining plants may not produce

viable seed until after they have regained their lost vigor, a matter of one or two seasons. On other sparsely vegetated lands, however, a stand of from 15 to 30 seedlings per meter, which is a satisfactory density on most soils, has been secured after the first year of deferred grazing.

The benefits of deferred grazing are not confined to areas which support plants of strong seed habits or those where the climate is particularly favorable to growth. Though on areas near and above timber line, where most of the forage plants reproduce vegetatively instead of by seed, deferred grazing does not tend to augment vegetation as it does on areas where the plants reproduce by the latter method, it does result in a permanent increase in vigor of the range plants and so promotes vegetative reproduction, which otherwise would be held in check by the premature removal of the herbage each season. In short, given a sufficient number of the original plants, deferred grazing is applicable wherever the vegetation is palatable after the seed crop has ripened and where water facilities will permit the range to be used in the autumn.

Before the deferred grazing system was thoroughly tried out, certain stockmen maintained that after seed maturity the palatability and nutritiousness of the herbage would be low and therefore that the season's forage crop would not only be wasted, but stockmen might be induced to keep their animals in the mountains until so late in the season that on account of the resultant loss of weight they would not be able to market them direct from the summer range.

To determine definitely the nutritive value of the forage after seed maturity, chemical analyses were made of the foliage of mountain bunch-grass, first, when the flower stalks were being produced, and again, at the time the seed ripened. The average of the tests showed that the young growing plant is 27.21 per cent richer in ether extract (fat) than the mature plant, while the latter slightly exceeds the former in protein (nitrogen). The mature plant also contains more crude fiber, but since the flower stalks are not consumed after the seeds are ripened that part of each specimen was eliminated from the tests. In comparison with timothy hay, mature mountain bunch-grass contains 94.39 per cent more protein, practically the same amount of ether extract, and 50.45 per cent less crude fiber, the last-named material being practically indigestible.

Nearly all the leading range plants, particularly the grasses, are grazed during the autumn with relish. It can not be said, however, that they are eaten with the same gusto after seed maturity as when they are growing vigorously. It was found that the first time a band of sheep passed over a matured range of medium density only about half of the forage crop was grazed off. Not until the range was grazed a second or third time was the crop entirely consumed. The vegetation on similar ranges grazed a month earlier was in most cases entirely con-

sumed the first time the stock passed over it. On ranges grazed after seed maturity the naked flower stalks, rising from leafless tufts of bunchgrass, remained after the stock had passed over them, but on ranges grazed when the forage was succulent and tender no flower stalks were visible after the passage of the stock. No appreciable amount of herbage remained on either area.

Sheep from several allotments where deferred grazing was practiced made fully as good progress as other sheep in allotments not handled under deferred grazing. By the time the seed has ripened, the milk flow of the ewes is nominal, and though it may decrease slightly when the animals are placed on the semi-air-cured forage, the lambs by this time are 4 or 5 months old, and milk is secondary to the nourishment secured through cropping.

Deferred grazing does not materially change the character of the forage on mountain ranges after seed maturity, because by this time succulent forage everywhere has been reduced to a minimum, leaving only the air-cured plants and on open grazing lands a small amount of second growth. By protecting part of the range until the last few weeks of the grazing season there is the possible advantage of having a reserve supply of solid feed upon which to harden the stock prior to the drive to market or to winter range.

The water facilities of the range may be an important consideration in determining whether or not to adopt the deferred grazing system. Regardless of the palatability of the forage, deferred grazing can not be carried out unless there is an adequate supply of water. On many ranges the water facilities may be improved by the construction of dams, the development and protection of springs, and even by digging wells and building windmills. Springs and small mountain streams are often replenished by the autumn rains.

SELECTION OF LANDS

The amount of range needed for grazing under the deferred system depends upon (1) the time at which the seed of the important forage plants matures and (2) the portion of the grazing season remaining after seed maturity. In the mountains of northeastern Oregon one-fifth of the grazing season remains after seed maturity. Accordingly, one-fifth of the carrying capacity, but not necessarily of the total acreage, of each grazing allotment may be reserved annually for purposes of revegetation. The lower the elevation the earlier, of course, does the seed mature and the greater the proportion of range which must be reserved for deferred grazing. Since the lands are usually grazed by camps, the carrying capacity of which is well known, the user will have no difficulty in determining what proportion of the range should be reserved.

MANAGEMENT DURING THE REVEGATION PERIOD

Once the area in need of revegetation has been selected, no stock should be allowed to graze on it until after the seed has ripened. Efforts should then be made to have the stock pass at least once over the entire area reserved, in order thoroughly to plant the seed.

In the second year of deferred grazing if a reasonably dense stand of forage seedlings has been secured, abusive herding must be avoided. While it may do no apparent harm, so far as future seed crops are concerned, to fully utilize the forage in the fall after the first year of protection, the loss of seedlings, even when the range is only moderately grazed, amounts to about 50 per cent. Close grazing and carelessness in permitting the stock to bunch and trail must necessarily increase this loss. Therefore, while close grazing after seed maturity the second year may result in increasing the forage seedling stand the following season, such an increase could only be temporary, since the practice causes severe loss among the seedlings already in existence. Moderate grazing after seed maturity also, of course, results in the destruction of a large number of seedlings, but the double advantage of utilizing the forage and planting an additional seed crop readily offsets this loss. Moderate grazing should be practiced in the second and subsequent seasons until the plants have reached full maturity and are permanently established. In the case of perennial plants this period is three years.

When the area selected has been thoroughly reseeded and the plants permanently established, another area in need of reseeding should be selected. This system should not come to an end when the range has been completely reseeded, but should be kept up in order to thoroughly maintain the vigor of the vegetation and allow for an occasional seed crop.

During the season of 1912 deferred grazing was in effect on 10 allotments in various portions of the Wallowa National Forest. In every case the carrying capacity of the range has increased materially, and the best interests of the stock industry seem to call for the adoption of the system generally.

SUMMARY

(1) Normally the spring growth of forage plants begins in the Hudsonian zone about June 25. For each 1,000 feet decrease in elevation this period comes approximately seven days earlier.

(2) In the Wallowa Mountains the flower stalks are produced approximately between July 15 and August 10, while the seed matures between August 15 and September 1.

(3) Even under the most favorable conditions the viability of the seed on summer ranges is relatively low.

(4) Removal of the herbage year after year during the early part of the growing season weakens the plants, delays the resumption of growth,

advances the time of maturity, and decreases the seed production and the fertility of the seed.

(5) Grazing after seed maturity in no way interferes with flower-stalk production. As much fertile seed is produced as where the vegetation is protected from grazing during the whole of the year.

(6) Germination of the seed and establishment of seedlings depend largely upon the thoroughness with which the seed is planted. In the case of practically all perennial forage species the soil must be stirred after the seed is dropped if there is to be permanent reproduction.

(7) Even after a fertile seed crop has been planted there is a relatively heavy loss of seedlings as a result of soil heaving. After the first season, however, the loss due to climatic conditions is negligible.

(8) When 3 years old, perennial plants usually produce flower stalks and mature fertile seed.

(9) Under the practice of yearlong or season-long grazing both the growth of the plants and seed production are seriously interfered with. A range so used, when stocked to its full capacity, finally becomes denuded.

(10) Yearlong protection of the range favors plant growth and seed production, but does not insure the planting of the seed. Moreover, it is impracticable, because of the entire loss of the forage crop and the fire danger resulting from the accumulation of inflammable material.

(11) Deferred grazing insures the planting of the seed crop and the permanent establishment of seedling plants without sacrificing the season's forage or establishing a fire hazard.

(12) Deferred grazing can be applied wherever the vegetation remains palatable after seed maturity and produces a seed crop, provided ample water facilities for stock exist or may be developed.

(13) The proportion of the range which should be set aside for deferred grazing is determined by the time of year the seed matures. In the Wallowa Mountains one-fifth of the summer grazing season remains after the seed has ripened, and hence one-fifth of each range allotment may be grazed after that date.

(14) The distribution of water and the extent of overgrazing will chiefly determine the area upon which grazing should be first deferred.

(15) After the first area selected has been revegetated it may be grazed at the usual time and another area set aside for deferred grazing. This plan of rotation from one area to another should be continued, even after the entire range has been revegetated, in order to maintain the vigor of the forage plants and to allow the production of an occasional seed crop.